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COMPLICATIONS OF GALLBLADDER SURGERY*

CHARLES GORDON HEYD, M.D.

NEW YORK

FROM THE DEPARTMENT OF SURGERY, NEW YORK POST-GRADUATE MEDICAL SCHOOL AND HOSPITAL, COLUMBIA UNIVERSITY, NEW YORK

COMPLICATIONS of gallbladder surgery may be reviewed as (1) mechanical, (2) chemical, (3) metabolic, and (4) infectious. The complications that occur within the first 24 hours after operation are obviously those that are associated with hemorrhage, gastric dilatation, embolism, pulmonary collapse, and cardiac dilatation. The early complications are those that arise from mechanical or infectious causes, such as: intestinal obstruction, volvulus, pyloric occlusion, peritonitis (local or general), subphrenic abscess, or retroperitoneal phlegmon. From the purely chemical background certain complications occur, secondary to continuous and repeated vomiting, such as alkalosis, hypochloremia, and hypohydration, or the acidosis from intractable diarrhea; or the complications of obscure or perverted liver chemistry—"liver deaths."

It is apparent that the postoperative complications in gallbladder surgery must be considered in reference to the operative procedures. Complications occurring after cholecystectomy or cholecystostomy are different from those that arise from surgery of the common duct. The association of cholelithiasis and carcinoma of the gallbladder is so well known as to require very little comment. The development of carcinoma after cholecystectomy or cholecystostomy, while extremely infrequent, is occasionally met with, and raises the question as to whether the malignancy was present at the time of the first operation. It is not a rare experience for a general surgical service to have a so called "cure" for a clinically diagnosticated carcinoma of the pancreas from a cholecystogastrostomy. There is always some degree of pathologic change in the wall of the common duct in every case of chronic gallbladder infection, and over 20 per cent of all patients with the symptomatology of gallbladder disease have liver and pancreatic involvement.

There is an abundant literature on the uncured cases of gallbladder surgery—the patients that have a continuance of their symptoms, or originate a new syndrome after surgical intervention. Complications do arise from mistaken diagnosis; from chronic glissonitis or fibrous perihepatitis; from continuing cholangeitis; from chronic interstitial pancreatitis; from benign stricture of the common duct; and from what has been inaptly called the

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postcholecystectomy syndrome, or by its new appellation—the "biliary dyskinesia," or sphincteritis of Oddi.

In order to visualize the subject matter of this paper, an analysis was made of 557 personal cases, both ward and private, that were submitted to laparotomy for diseases of the gallbladder or the external biliary duct system. It seemed pertinent to inquire: How many of these patients survived surgery? And of those who died: What was the mechanism of death? Were the preoperative preparation, the surgical intervention, and the postoperative therapy competent and adequate? Furthermore, could any reasonable deductions be made as to the complications and mortality that would serve to prevent their occurrence in any future group of patients? All the patients were personally operated upon by the author, so that the descriptive terms used are common to his habit of mind, and probably differ little from case to case. To be sure, a better showing could be made if the analysis had been confined to private patients alone. Irrespective of the competency of the surgeon, the relative physical well being, the stage of the disease, and the patient's hereditary background are factors of undoubted importance in insuring recovery after surgical intervention. It seemed wiser, however, to take the "run of the mill," for the conclusions derived therefrom would be applicable to the gallbladder service in any general hospital of like prominence and bed capacity.

TABLE I

STATISTICAL RÉSUMÉ OF BILIARY TRACT SURGERY

Classification	Total	Per Cent
Number of gallbladder cases	557	
Males	143	25.7
Females	414	74.3
Cholecystectomy	500	89.7
Choledochotomy	26	4.6
Cholecystostomy	34	6.1
Cholecystectomy plus appendicectomy	363	72.6
Cholecystectomy plus choledochotomy	12	2.1
Cholecystectomy or choledochotomy plus stomach operation	55	9.8
Cholecystogastrostomy	5	.89
Cholelithiasis	330	59.2
Noncalculous cholecystitis	222	39.8
Associated with ulcer of the stomach or duodenum	59	10.5
Associated with jaundice	91	16.3
Associated with pancreatitis	21	3.7
Associated with fibroids	54	13.0
Associated with diabetes	5	.89

The observer is impressed with the comparative rarity of subphrenic abscess as a complication of gallbladder disease. There were only two recorded instances of this condition in the series. It would seem reasonable to suppose that subdiaphragmatic infection could be expected in a higher percentage of cases. Our experience has been that subphrenic abscess is usually sequential to suppurative appendicitis and gastroduodenal ulceration. The roentgenologist, however, not infrequently reports subdiaphragmatic pathology when the roentgenograms are taken within the first week or ten days after a gallbladder operation. Sterile or infected bile does escape in approxi-

mately 10 per cent of gallbladder operations, and makes its way into the posterior superior portion of the right subdiaphragmatic space. Fixation or even elevation of the right diaphragm would then be a roentgenographic finding. It is rarely, however, that this condition leads to abscess formation, as the majority of these infections subside spontaneously.

Cholecystectomy for chronic gallbladder disease is one of the safest of all intra-abdominal operations, and in the hands of a reasonably well trained surgeon is relatively free from postoperative complications. Operations upon the gallbladder or bile ducts when in an acute inflammatory phase are associated with an increase in the technical difficulties, and the development of complications. An operation undertaken upon a patient with obstructive jaundice is associated with greater technical difficulties, and a very marked increase in the frequency of complications. This is evidenced by an ascending mortality scale. In 500 noncomplicated cholecystectomies, the mortality rate was 3.3 per cent. Yet in 34 cases of cholecystostomy for acute cholecystitis, there were five mortalities, or 14.7 per cent. In 500 cases of cholecystectomy, the appendix was removed in 363, or 72.6 per cent of the cases. There were 55 patients, or 9.8 per cent of the series, who required in addition to surgery of the gallbladder or biliary duct another major operative procedure—gastro-enterostomy, gastric resection, or pyloroplasty.

Postoperative hemorrhage in patients operated upon for obstructive jaundice due to common duct disease is a formidable danger. Preoperative therapy has for its object the obtaining of two desirable conditions: (1) To make the surgery safe for the patient, and (2) to render the patient safe for the surgery. Preoperative therapy for bleeding, while fairly satisfactory, is by no means adequate. In the postmortem examination of patients who have died after common duct operation for obstructive jaundice there was found in the peritoneal cavity in 40 per cent of the patients an amount of intraperitoneal blood that was a complicating factor in producing death. This postoperative capillary bleeding occurred in individuals who had been rendered relatively safe by obtaining a normal bleeding time, and a safe coagulation time before operation.

Acute or subacute pancreatitis is a complication of gallbladder surgery with great mortality possibilities. I do not refer to fulminating hemorrhagic pancreatitis, but indicate a pancreatitis characterized by acute edema of the head of the pancreas, pressure necrosis of the capsule, and the escape of pancreatic ferment. The possibility of pancreatitis should be anticipated when a male patient is seen during an acute attack, and presents a history of gallbladder disease. In addition to the general clinical picture of gallbladder disease with biliary colic, there are certain significant features not ordinarily present in the gallbladder history. The patient complains of intense pain transversely above the navel and extending across both sides of the abdomen, and at almost the same location across the back. The temperature remains constantly elevated, and there is always some degree of icterus.

On opening the abdomen the surgeon should be on the alert for small areas of fat necrosis. These may occur as minute white semicrystalline deposits on the omentum or gallbladder. The gallbladder is edematous and

usually contains stones. Marked hypervascularization exists through the entire right upper quadrant. The gallbladder will ordinarily be surrounded by the omentum, and the foramen of Winslow will be obliterated by fibrinoplastic lymph material. On separating the omentum a peculiar "prune juice" fluid escapes from Morrison's space. This fluid is a very intense chemical ferment, and produces a pale green, gangrenous area wherever it contacts.

Pancreatitis occurred 21 times as a complication in 557 cases of gallbladder disease, representing 3.7 per cent of the series, with five deaths, or a mortality of 23.8 per cent. It occurred five times as frequently in the male as in the female. The causes of death in the gallbladder cases complicated by pancreatitis were as follows: (1) auricular fibrillation, death occurring on the eighth postoperative day; (2) pulmonary embolism, the patient dying at the end of 48 hours; (3) retroperitoneal phlegmon, with death on the twelfth day; (4) peritonitis, death occurring on the eleventh day; and (5) wound dehiscence with secondary intestinal obstruction, when the patient died on the twenty-second day. It is an interesting observation that the immediate postoperative condition of the male with a gallbladder and pancreatic condition is as a rule more disturbing and complicated than a similar condition in the female; yet the eventual relief of symptoms in the male is equal if not better after full recovery than that which obtains in the female.

In the 557 cases there were 13 malignancies of the gallbladder or ducts, representing 2.3 per cent of the material. All the cases of malignancy were jaundiced, all had gallstones, two were associated with nonmalignant duodenal ulcer; and four died in the hospital, the remaining dying within ten months after leaving the hospital. In one of these patients a resection of the adjacent liver was carried out, with no apparent increase in longevity. Carcinoma of the gallbladder *per se* is not the insurmountable difficulty, but it is the dense metastatic glandular deposits along the hepatic and common ducts, bringing about the inevitable compression and occlusion, with continuous deepening jaundice, that render the condition beyond the resources of surgical intervention. Mechanical hemorrhage from a nonligated vessel, in contradistinction to capillary bleeding in jaundice, is, under present technical conditions, seldom a complicating factor. Visible secondary hemorrhage was noted in only three instances, and in none of these individuals was it anything but an embarrassing feature. The bleeding occurred from branches of the superior epigastric, and was not in any way noteworthy.

The frequency of gallstones increases with each decade of life. Gallstones were found by Gross in 8 per cent of 9,531 postmortem examinations, 8.1 per cent of the gallstones being found in the fourth decade, 14.7 per cent in the fifth, and 21.2 per cent in the sixth. In our series, gallstones were present in 59.2 per cent of the cases, being absent in 39.8 per cent. The average age of the patient at operation was 40.4 years, the youngest being eight years of age, and the oldest 79.

The ascending age incidence of gallstones parallels the normal or pathologic degenerative changes in the human being. It as a matter of clinical observation that the best results in gallbladder surgery are obtained in the young individual, and that the postoperative sequelae of indigestion and pain

are more apt to continue in the patients who have surgery in the fifth, and even more so in the sixth, decade.

In 414 female patients, 54 or 13 per cent of the series had fibromyomata; and 59 or 10.5 per cent had ulcer either of the stomach or duodenum. In 500 cases of cholecystectomy there were 16 deaths, representing a mortality of 3.7 per cent. Four died of pneumonia, two of myocarditis, one of Streptococcus septicemia on the sixteenth postoperative day. There were two deaths from embolism, one from intestinal obstruction following dehiscence of the laparotomy wound, two from peritonitis, in one of which there was gangrene of the ascending colon on which avertin was employed. There were eight liver deaths—two with hyperpyrexia and coma, and three with diminishing jaundice and coma, and three with hepaticorenal syndrome. Of the 16 deaths, 15 had calculous gallbladders, one was a noncalculous cholecystitis, and one was a secondary cholecystectomy for a retained calculous gallbladder.

In 557 gallbladder cases, cholecystostomy was performed 34 times, with five deaths, representing a mortality of 14.7 per cent. Four of the five cases had biliary calculi, and all were gangrenous. Three had had spontaneous perforation with free fluid in the peritoneal cavity. The cause of death was assigned as follows: peritonitis—three cases; myocarditis and nephritis—one case; acute yellow atrophy of the liver—one case. There were two deaths following cholecystostomy plus choledochotomy. One occurred on the thirty-third postoperative day from cardiorenal disease, and the other occurred in a patient markedly jaundiced and in a semicomatose condition. The operation was performed under local anesthesia, and the patient died at the end of 36 hours, in coma. One patient died in coma from hepatic degeneration with intense nonobstructive jaundice. We have attributed this mortality to chronic arsenical poisoning. Two deaths occurred in patients having secondary operations on the gallbladder tract. One mortality followed duodenorrhaphy, with a posterior gastro-enterostomy for a cholecystoduodenal fistula. A second mortality occurred in a patient having a choledochogastrostomy performed for stenosis of the common duct, following a cholecystectomy performed elsewhere.

Of more importance, and about which we have very little substantial knowledge, is the condition of the liver, both immediately before operation and its career subsequent to surgical intervention. The multiplicity of functions exercised by the liver and the inadequacy of any test at the present time to give a real picture of hepatic function render the preoperative appraisal of liver function extremely difficult. Continental observers have described in numerous publications a condition of liver insufficiency. When it is recalled that deficiency of liver function may exist in any one of a number of categories, and yet at the same time the liver may exercise normal function in its other properties, it is difficult to determine any specific type of hepatic insufficiency by any of the standards of measurement that we now possess. It seems reasonably clear that there are grades of hepatic degeneration which follow relatively mild infections, and exhibit themselves as catarrhal jaundice, or as the more grave and lethal condition of acute yellow atrophy.

TABLE II

STATISTICAL RÉSUMÉ OF MORBIDITY AND MORTALITY FOLLOWING GALLBLADDER SURGERY

Classification	Total	Per Cent
Number of gallbladder cases	557	
Average age	40.4 yrs.	
Age of oldest patient	79 yrs.	
Age of youngest patient	8 yrs.	
Duration of stay of cholecystectomy group	16.4 days	
Duration of stay of common duct group	21.9 days	
Deaths after cholecystectomy	16	3.3
Deaths after cholecystostomy	5	14.7
Deaths from pancreatitis complicating gallbladder disease	5	23.8
Deaths from malignancy of the gallbladder or ducts (hospital deaths)	4	
Deaths from gallbladder disease complicated by stomach or duodenal ulceration	9	16.1
Total deaths	39	7.0
Liver deaths	8	20.5
Postmortems	7	17.8
Dehiscences	4	.7
Secondary hemorrhages	3	.5
Intestinal obstruction subsequent to operation	3	.5
Malignancies	13	2.3

In previous publications[1, 2] we have indicated the effect of the edema of the liver parenchyma as it occurs with degeneration of the liver cells. It is interesting to speculate as to what permanent damage is done to the liver after a long period of obstructive jaundice. Experimental evidence is abundant that regeneration of liver substance takes place with surprising rapidity. But what degree of fibrous or cicatricial repair has taken place in the liver during recovery, and how great is the permanent effect of the fibrosis that remains in the liver? We have been impressed in the course of surgical intervention for gallbladder disease to find varying degrees of fibrous hepatitis, the leathery character of the liver, its changes in color; and it is our impression that postoperative localized residual pain in the general area of the liver, particularly in the midaxillary line, is the result of sensory nerve disability from a chronic glissonitis.

On October 24, 1923, I presented before this Society a paper entitled "The Liver and Its Relation to Chronic Abdominal Infection."[3] In this connection I must borrow from my former self, on the old Greek principle that a man may once say a thing as he would have said it, but he cannot say it twice. The complications that may reasonably be expected after laparotomy for gallbladder disease are clearcut and distinct, and possess within certain limits a chronologic sequence. In the first 24 hours the complications are anatomic, such as hemorrhage, shock, gastric dilatation, and embolism. In the succeeding 48 to 72 hours the element of infection might possibly come into play, with the production of a peritonitis, and still later, abscess formation. We have observed occasionally three clinical states that supervene after operations on the gallbladder and biliary system, and more rarely after gastric or intestinal surgery, and which cannot be attributed to any of these factors. Although these clinical complications are comparatively rare, yet they are

definite, and apparently within their group are rather characteristic in their symptomatology. The most common type of chemical or so called "liver deaths" have been those associated with hyperpyrexia and coma. The operation has been one of relatively simple technical performance in a patient whose general metabolism was considered satisfactory before operation and in whom adequate renal function had been determined. Almost immediately from the time of operation there is a continuously ascending temperature, with a rapidly developing lethargy, stupor and coma, and death terminates the picture in 18 to 36 hours. A second type, somewhat less frequent than the first, occurs in patients who have had an operation for the relief of obstructive jaundice and in the course of a rather normal convalescence, about the fourth or fifth day, and in the presence of a constantly diminishing jaundice as indicated by the icterus index, they slowly pass into a stupor and coma and the exodus is in no way dissimilar from the cholemic death that occurs in unrelieved obstructive jaundice. A third type, perhaps, is associated with some unrelated kidney pathology, for anuria is a factor in the terminal picture. Previous to operation these patients have had what was considered normal renal function and no question was in the mind of the surgeon as to the competency of the kidney to carry on its function in the presence of an operative intervention. Forty-eight hours after an operation on the gallbladder or common duct the patient, quite rapidly, presents a picture not dissimilar from shock, with cold, clammy skin, gradual failure in water elimination and a rise in the urea nitrogen. The urinary output becomes less and less, and a mild delirium develops with increased frequency of pulse and temperature and finally coma and death. These patients were not jaundiced either before or after operation, and there is a distinct interval of apparently normal postoperative conduct of from 24 to 36 hours between the operation and the onset of the terminal clinical picture. Whether these three types are clinical entities or not is not important at the present time. They serve as indications or examples of a complex chemical problem presented to gallbladder surgeons.

In the 39 mortalities in our series of 557 cases, there were eight which could not be ascribed to the ordinary causes of death. Two of the cases were characterized by hyperpyrexia and coma, following very shortly after surgical intervention and progressing to death. Three cases were operated upon for chronic obstructive jaundice, and after varying intervals of five to seven days of good postoperative progress, and in the presence of a diminishing icterus, slowly developed coma and died. There were three cases, two cholecystectomies and one a cholecystectomy, that at the end of 24 to 36 hours developed a pronounced cardiorenal collapse, with cold, clammy skin, presenting the picture of profound shock, and slowly but progressively failed and died.

While clinical observation has remained substantially correct, the interpretation must await further experimental evidence. The third group is apparently linked up with hypohydration, and the interpretation of the blood chemistry with a high nonprotein nitrogen is significant only by reason of

the great demand on the part of the patient for the preservation of his preferential water. It requires a certain urine water volume to carry away the excrementitious chemicals, and with any great loss of urine water volume there is a backing up of nonprotein nitrogen in the blood. The continuance of this blood retention certainly invokes a vicious circle, and establishes a repetitive assault upon a liver that is already beginning to fail.

CONCLUSIONS

(1) That certain mortalities from the very nature of the disease cannot be prevented. The 13 malignancies in this series at the time of operation were beyond any remedial measures. It is highly significant that all of them had gallstones and symptoms of long continued gallbladder disease. Surgical intervention at a period of early symptomatology would have completely obviated this group of mortalities.

(2) A gallbladder disease characterized by biliary colic means the interplay of two factors: (a) the mechanical effect of the calculus, and (b) the rapid increase in the degree of infection. The high percentage of mortality in the cholecystostomy cases is directly attributable to surgical procrastination. Four out of five patients had calculi. It seems axiomatic that biliary colic provides one of the surest indications for surgical intervention.

(3) Biliary disease characterized by colic, in males, carries with it a very definite possibility of pancreatitis, with its high operative mortality.

(4) Grave cardiovascular renal disease and pneumonia account for a considerable group of, so far as we know, unpreventable mortalities. Their lethal possibilities can be lessened by longer preoperative therapy.

(5) There is a striking contrast in the ability of patients to withstand the ravages of gallbladder disease, and the surgery necessary for its correction. This resistance depends upon the social, economic, and nutritional level of the patients. Of the 557 patients, 417 were private and 140 were clinic patients. Of the 417 private patients, 20 died, giving a gallbladder mortality in private patients of 4.8 per cent. In the 140 clinic patients, 19 died, giving a gallbladder mortality in clinic patients of 13.5 per cent. This noteworthy difference of mortality rate between private and clinic patients is due to the greater degree of pathologic damage in the clinic patient as the result of delay in seeking surgical intervention at an early stage of the disease.

(6) With due consideration of all of the factors involved—the type of lesion, the biologic background of the patient, the adequacy of surgical intervention, the complications and the mortalities—still, surgery for gallbladder disease is safe and highly satisfactory.

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MORTALITY IN SURGICAL DISEASES OF THE BILIARY TRACT*

AN ANALYSIS OF ONE HUNDRED AND THIRTY AUTOPSIES

RALPH COLP, M.D., AND LEON GINZBURG, M.D.

NEW YORK

FROM THE SURGICAL SERVICE AND PATHOLOGIC LABORATORIES OF THE MOUNT SINAI HOSPITAL, NEW YORK, N. Y.

THE past two decades have witnessed a gradual and progressive decrease in the general surgical mortality reported by the larger clinics. In addition to earlier diagnosis and improved surgical technic, this may be attributed to a better understanding of the pathologic, physiologic and chemical changes occurring in the course of disease. As a result of this increased knowledge, a better selection of cases has become possible as well as the election of the most opportune time for operative intervention. The surgical treatment of obstructive and infectious processes affecting the biliary tract has shared in this general advance. Many important problems remain, however, which must be solved before the mortality statistics in this group of cases can be viewed with satisfaction.

The present study is based upon 130 consecutive postmortem examinations of biliary tract disease gathered from the ward services of the Mount Sinai Hospital, New York City. These include deaths following operations and those cases of nonmalignant disease which were admitted in such desperate condition that operation could not be undertaken. Many of the deaths represent the unavoidable end-results of the economic circumstances prevalent in any group of patients admitted to the wards of the average large metropolitan hospital.

A consideration of the causes of death immediately discloses that from the practical standpoint, they fall into three major groups. In the first group the disease itself was the ultimate cause of the fatal issue. The opinion is still too widely held that cholecystitis and cholelithiasis are relatively benign and harmless conditions subjecting the patient to minor digestive complaints and an occasional severe attack of colic, which can be readily controlled by morphine. The knowledge that cholelithiasis and biliary infections are very often clinically silent, although actually treacherous foci of chronic infection and obstruction, should be more widely diffused. A prolonged period of persistent low grade infection and partial obstruction induces local and systemic changes which weigh the odds heavily against successful surgery. Indeed, either a sudden unaccountable accession of virulence in the infective process, or a superimposed complete obstruction, inevitably earmarks many of these cases for death regardless of the acuity of judgment, the facility of technic,

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or the postoperative care afforded to them. This group includes cases of acute diffuse peritonitis complicating acute cholecystitis and perforation of the gallbladder, calculus suppurative cholangeitis, suppurative pylephlebitis and hemorrhage associated with obstructive jaundice.

In the second group, (II-A) are the so called interval cases in which the disease at the time of operation was not threatening to life. Death in these instances may be traced directly either to errors in judgment or technic in their widest sense, or to those complications or accidents which in the present state of surgical development seem to be an unavoidable accompaniment of major surgery involving the upper abdomen. These cases consist of postoperative peritonitis, operative injuries to the extrahepatic bile ducts, postoperative pneumonia, cardiac failure, pulmonary embolism and wound rupture. Cases dying from uremia and the so called hepatorenal syndrome will also be discussed in this group. In addition, there is another small but important group, (II-B) of cases of primary hepatic disease which were mistakenly operated upon for gallbladder disease.

The third group consists of those autopsies in which carcinoma was the complicating factor.

Group I.—*Diffuse Peritonitis.*—This is not only the most important and the most common complication but the one which should be the most susceptible of surgical prevention.

Fatal cases of diffuse peritonitis in gallbladder surgery may be divided into those in which the pathology is already well developed at the time of operation and represents an extension of the infectious process from an acute cholecystitis, and those in which the operative procedure is either a directly causative or an exciting accessory factor. The type of peritonitis may be arbitrarily divided into a biliary and suppurative variety.

There were 12 cases of biliary peritonitis, six of which resulted from a perforation of an acutely inflamed gallbladder, and will be discussed under "peritonitis following acute cholecystitis," and six of which followed operation.

These particular cases of bile extravasation ran a short and usually fulminating course, probably due to the fact that the bile was infected. B. coli was isolated from the cultures of the peritoneal fluid made at secondary operations in three cases. The rapidly fatal outcome in these patients stood in marked contrast to the relatively benign course seen and reported either in biliary effusions secondary to nonoperative traumatic injury of the ducts, or operations on apparently noninfected gallbladders.

Five of the six cases of postoperative *biliary peritonitis* could be traced to definite technical operative errors. Accidental lateral injuries to the hepatic duct in the course of a cholecystectomy resulted in necrosis and perforation of the duct wall in two instances. In one case the extravasation of bile was the result of a false passage made in an attempt to probe the common duct with a fine probe via the cystic duct. In another, the extravasation occurred from the distal portion of the cystic and the adjacent portion of the

common duct, after the cystic duct, which had been completely split in order to remove calculi from the choledochus, was resutured. No hepaticus drainage was instituted. A unique and rather unusual source of a fatal biliary leak resulted from necrosis of a portion of the gallbladder wall to which an ovarian clamp had been applied in order to facilitate freeing of the gallbladder from adhesions. Cholecystectomy, however, was not performed. This case emphasizes the inadvisability of applying a crushing clamp to the viscus unless its ablation has been definitely decided upon. The final case was one of a retroperitoneal biliary extravasation which even a postmortem examination could not clarify. The source of the leakage could not be detected after a most careful and painstaking search.

Drainage is used routinely following cholecystectomy at this institution. It is evident from these autopsies that the presence of a drain is not an absolute guarantee against the consequences of a large biliary extravasation. As a matter of fact, in two of these cases there was no biliary discharge through the tube. But if drainage were dispensed with, it is likely that biliary peritonitis would probably have been more frequent.

Suppurative Peritonitis occurred in seven instances following operations for chronic conditions involving the gallbladder and extrahepatic ducts. Five of these followed secondary procedures upon the ducts, and three were associated with operative injuries of the duodenum and colon. Peritoneal infections occurred twice following technically difficult and prolonged operations for subacute and chronic cholecystitis. Although both these cases were adequately drained, oozing from the liver bed resulted in the development of a subhepatic hematoma. The Clostridium welchii was recovered from the blood clot and wound. The clinical course, however, was not that of a gas bacillus infection, and at the postmortem the colon bacillus was recovered from the peritoneal fluid.

Diffuse Peritonitis Resulting From Acute Cholecystitis.—Nine such cases were found at postmortem. Five had been operated upon. The other four had been admitted to the hospital in such a critical condition that any operative procedure was deemed either inadvisable or impossible. Two points were striking. In the first place, diffuse peritonitis due to perforation of the gallbladder occurred in elderly patients, one being over eighty, two over seventy, two in the sixties, and one in the late fifties. The one patient who was under fifty was extremely obese and a severe diabetic. Secondly, this fatal complication of perforation into the free peritoneal cavity apparently occurred during the first attack in half of the cases and the clinical course was so atypical in three that the only preoperative diagnosis possible was peritonitis of unknown etiology. There were altogether seven such perforations into the free peritoneal cavity, in five of which the peritoneal fluid was definitely biliary in character. In two other instances the cystic duct had apparently been blocked off long enough to permit of the absorption of the bile pigments from the gallbladder before perforation occurred.

There was a single case of rupture of a pericholecystic abscess. This oc-

curred immediately following a gastro-intestinal fluoroscopy undertaken because of the atypical character of the patient's symptoms. This episode was initiated by terrific attack of pain and shock resembling perforation of a duodenal ulcer. Operation was performed within a few hours, but the patient succumbed of peritonitis at the end of three weeks.

There was also an interesting case of diffuse biliary peritonitis associated with gangrene of the gallbladder but without any visible defect in the gallbladder wall.

It is significant that no case of diffuse peritonitis following cholecystectomy for acute cholecystitis was found, except in those cases in which a suppurative peritonitis was already present at the time of operation. Judging from this series, operation during the acute phase, as is the custom of some of the surgical services, or after the acute condition has subsided, as is the practice on the others, does not seem to materially affect the occurrence of a fatal postoperative peritonitis. This point together with the knowledge that acute peritonitis from an acutely inflamed gallbladder already present at operation, accounted for almost one-third of the deaths in acute cholecystitis found at postmortem, would seem to be very strong arguments for early operative intervention in acute gallbladder infections. However, it is important to note that most of these cases occurred in elderly patients and that in a number of instances the clinical course was very atypical. It must also be emphasized that no cases of acute gallbladder perforation were found in young or middle-aged groups who were otherwise in good health.

TABLE I

CAUSES OF DEATH IN INSTANCES OF ACUTE CHOLECYSTITIS

Cause	Number
Peritonitis, diffuse	9
Pylephlebitis	6
Subhepatic abscess	1
Subphrenic peritonitis abscess	1
Hemorrhage	1
Duct injuries	1
Pneumonia	2
Sepsis	1
Pancreatitis	1
	23

Suppurative Calculus Cholangeitis.—This serious complication and its sequelae were the causes of death in 14 cases of gallbladder disease associated with choledochal stone. These patients were advanced in years, five being over 70, six being in the 60's, and one in the 50's. There were two patients under 50, one of whom had been subjected to a previous cholecystectomy and the other had a 20 year history during which time the gallbladder had been practically destroyed. All but one gave a history of one or more attacks of jaundice over a period of three to five years. The exception was a diabetic in whom no history of jaundice prior to the fatal attack could be obtained.

When the final attack came on symptoms developed with marked rapidity. In half the patients the illness had lasted only between two and five days before the admission to the hospital.

Of these 14 patients, six entered the hospital so desperately ill that nothing could be done and death ensued within 24 to 36 hours. All were jaundiced and had repeated episodes of fever and shaking chills. Bacteremia was present in three, B. coli, B. Friedländer, and a pneumococcus being recovered respectively. In these unoperated cases, postmortem revealed a complete obstruction due to the impaction of a stone in the vicinity of the ampulla in three. In the remainder, although multiple stones were present, the obstruction was incomplete.

Eight cases succumbed to the effects of suppurative cholangeitis in spite of surgical interference. The general condition in four was such that operation was undertaken as a last resort, the surgeon being fully cognizant of the hopelessness of the situation. In two the condition of the patients was such that only a simple cholecystostomy was performed under local anesthesia trusting that the drainage and decompression thus afforded would tide the patient over the critical phase of the disease. Death soon followed and at postmortem, multiple hepatic abscesses were found in three and the fourth presented a diffuse cholangeitic hepatitis.

There were only four cases in which the surgeon had felt that operative intervention promised a favorable outcome. Even this hope proved unwarranted because in two the postmortem examination revealed that the disease had been more advanced than was anticipated. Multiple hepatic abscesses and a suppurative pancreatitis were present in one, while in the other, in which the gallbladder had previously been ablated, a severe diffuse cholangeitic hepatitis with marked liver degeneration was found.

Errors in operative technic and judgment contributed to the fatal outcome in the two other cases. In one, cholecystectomy with ligation of the cystic duct was performed for a gangrenous cholecystitis. A stone impacted at the papilla was overlooked. In view of the fact that the patient was jaundiced, drainage of an open cystic duct would have been a better procedure. In a second instance a choledochostomy was performed and a subhepatic abscess drained. The patient did not do well postoperatively. A subphrenic abscess was suspected but its presence could not be proven even after repeated exploratory aspiration. It was found at postmortem three weeks later.

These cases of suppurative calculus cholangeitis are a sad commentary on conservative medical therapy. The only method by which incidence of the high morbidity and mortality in this group may be reduced, is earlier operation instituted at a more favorable period in the course of the disease.

Suppurative Pylephlebitis.—This complication was found to be the cause of death in six cases of acute cholecystitis and two of cholangeitis. In addition, it was a contributing factor in five cases of suppurative cholangeitis. It is not to be considered as an isolated lesion, but rather as the most fatal complication of a diffuse and virulent infection. Four modes of involvement

TABLE II

CAUSES OF DEATH IN INSTANCES OF COMMON DUCT STONES

Cause	Number
Suppurative cholangeitis	14
Suppurative pylephlebitis	2
Peritonitis	2
Subphrenic abscess	1
Subhepatic abscess	1
Ileus	1
Duodenal fistula	3
Hemorrhage	2
Uremia	3
"Extrarenal azotemia"	4
Pneumonia	2
Cardiovascular	2
Pancreatitis	2
Unrelieved jaundice	1
Biliary cirrhosis	1
Sepsis	1
Common duct strictures	7
	49

of the portal vein were noted. The first type was characterized by a direct extension along the course of the cystic vein. In the second it resulted from a periportal abscess or a severe phlegmonous infection within the cellular tissues of the hepaticoduodenal ligament. In the third type involvement of the small veins lying upon the surface of the common duct resulted from a virulent necrotizing cholangeitis. The fourth variety was characterized by the development of an abscess between the deep surface of the gallbladder and the liver. A local phlebitis of the intrahepatic radicals at this point occurred with a retrograde extension into the right branch of the portal vein. It is noteworthy that four of the cases which developed pylephlebitis on the basis of severe common duct infection occurred in cases in which the gallbladder had either previously been removed or had become shrunken and nonfunctioning as a result of cholecystostomy or prolonged disease. The gallbladder seems to act as a sort of safety valve in cases of common duct infection, and the clinical course appears to be more fulminating when this gallbladder function has been eliminated. Blood culture studies revealed the presence of B. coli in three instances, B. Friedländer in two, and Streptococcus viridans and Staphylococcus aureus each in one instance. In five of these seven instances a thrombophlebitic process was noted in the intrahepatic radicals of the hepatic vein. Multiple pylephlebitic liver abscesses were found in four of the six cases complicating an acute cholecystitis. In the cases associated with cholangeitis, liver abscesses of pylephlebitic origin were found twice.

The clinical picture was variable. In some there was a fulminating course with death within the first week. Others presented a more classic picture of pylephlebitis with a septic temperature and recurrent chills which at times

lasted for weeks. In two instances the infectious processes seemed to undergo a certain subsidence and a uremic picture predominated. Postmortem in one of the latter instances showed that the still active suppurative focus had been blocked off from the venous circulation by obturating thrombi which extended backward into the splenic, gastric and superior mesenteric veins.

Reviewing these cases from the standpoint of possible operative intervention, only one case was noted in which earlier operation might have been successful. This patient had been treated conservatively for one week, during which time evidences of a severe gallbladder infection became more marked. Operation revealed that an abscess had developed between the gallbladder and the liver bed from which a fatal pylephlebitis developed.

Hemorrhage.—There were no fatal hemorrhages due to a technical failure to adequately secure the cystic vessels in the course of a cholecystectomy. In one instance, however, the control of a severe hemorrhage was achieved only after injuring the hepatic duct. The one fatal hemorrhage from the cystic vessels occurred ten days postoperatively in a case in which a cholecystostomy and drainage of a pericholecystitic abscess had been performed. Autopsy disclosed the source of bleeding to be from an erosion of the cystic artery. This was the result of sloughing at the junction of the ampulla of the gallbladder and the cystic duct. No fatal hemorrhage occurred from the liver bed in nonjaundiced cases. The formation of a subhepatic hematoma, however, provided a nidus for the development of a fatal peritonitis in two instances.

Hemorrhage in obstructive jaundice due to stone was dependent usually on factors aside from technical errors. Postoperative exsanguinating hemorrhage *per se* accounted for only three deaths even in these exceptionally poor operative risks. The tendency to fatal hemorrhage seemed to bear no constant relationship to the intensity of the icterus. The van den Bergh test in three of these cases was 6.5 mg., 3.0 mg., and 1.0 mg., respectively. These three cases were afebrile and complained of a rather severe pruritus. In all of them choledochostomy had been supplemented by cholecystectomy. The latter procedure with its potential source of hemorrhage from the gallbladder bed is especially dangerous and should be avoided if possible in cases of common duct obstruction with jaundice.

White bile was present in the common duct in one instance. The fatal hemorrhage commenced on the fifth day in two patients and on the tenth day in the third. There was a definite increase in the jaundice following hemorrhage. This was due to bleeding into the common duct with subsequent clot formation and the recurrence of an obstructive jaundice in one case. Hemorrhage severe enough to be fatal occurred in nine of 26 deaths associated with carcinomatous obstruction, and in two of seven deaths associated with strictures of the duct. The relatively small incidence of fatal hemorrhage in cases of stone may be partially accounted for by the fact that many deaths occurred from an overwhelming infection at a period before the tendency to bleed had become fully developed.

It must be emphasized that these figures reveal only the cases of *fatal* hemorrhages found at postmortem. Severe postoperative hemorrhage is still quite common in jaundiced patients. The repeated use of small transfusions and glucose intravenously have apparently been potent factors in reducing the number of fatalities formerly attributable to this cause.

From a clinical standpoint, it may be remarked that a few cases were considered to have developed a concealed internal hemorrhage from the signs of collapse and rapid pulse. Postmortem examinations did not substantiate this diagnosis. The clinical picture was undoubtedly due to the development of a fatal suppurative process.

GROUP II-A.—*Operative Injuries and Traumatic Strictures of the Extrahepatic Bile Ducts.*—Deaths attributable to duct injuries may be divided into the immediate and the remote. Three deaths occurred as a result of operative injuries to the ducts in the immediate postoperative period. In two of these, a cholecystectomy was performed after primary ligation of the cystic duct and vessels. The operation was relatively simple and the ducts were specifically described as being well visualized, and there was not the slightest suspicion that a serious injury had occurred. In the third, cholecystectomy was begun at the fundus in a very obese patient with an acute cholecystitis. The operation was difficult and complicated by hemorrhage. It was feared at the time that injury of the duct had occurred in an attempt to control the bleeding.

The hepatic duct was injured in all these cases, and in two there was simultaneous injury of its right branch. Anatomically no abnormalities were noted. In one instance, the ligature completely encircled the duct producing a picture of an increasing obstructive jaundice. In the other two cases the application of a lateral ligature to the duct wall produced a slough which permitted the escape of bile into the peritoneal cavity. This gave rise to a fulminating peritonitis, mainly subphrenic in distribution. While external tube drainage had been instituted in both these cases, there was no biliary drainage for a few days in one.

In addition to these three cases in which death occurred in the immediate postoperative phase, there were seven cases in which death was the eventual sequela of a previous operative injury to the duct. Two of these cases had their original operation performed at this institution and five elsewhere. A consideration of these cases in detail would take us too far afield. A few points, however, deserve mention.

Symptoms appeared within three months in three cases, within six months in three, and in five years in one case. There was a history of a biliary fistula which underwent spontaneous closure in four instances. The others had only transient biliary drainage. The duration of life following the onset of symptoms due to stricture was over four years in three (four, five and nine), and under one year in three. In the cases with a relatively long duration of symptoms a definite explanation was found at postmortem. In one, the stricture was only partial, the patient dying of suppurative cholangeitis. In the

second, a spontaneous fistula had developed between the duodenum and right hepatic duct through which bile entered into the duodenum. The patient, however, developed biliary cirrhosis and died at the end of five years. One patient who lived for nine years had an external biliary fistula which opened and closed spontaneously. She finally died of hemorrhage into the duct system and externally following an attempt at dilatation of the sinus.

Three patients died within eight months after the onset of symptoms due to stricture. One died of suppurative cholangeitis, and the other two of a complete biliary obstruction necessitating operation. One died from postoperative hemorrhage, and one died from peritonitis following a choledochoduodenostomy.

The site of the stricture was in the hepatic duct proximal to the entrance of the cystic in five cases, and in the common duct distal to the cystic in two. One of the latter was the result of an injury which occurred during a gastrectomy for duodenal ulcer.

In four instances biliary cirrhosis with splenomegaly was found. In two other cases there was a marked chronic cholangeitis with periductal fibrosis.

These unfortunate deaths again emphasize the unrelaxing vigilance which must be maintained when approaching the region of the cystic duct and vessels. Morphologic variations are quite common and long standing inflammation further distorts the ordinary anatomic relationships. Retrograde cholecystectomy should commence with the exposure and visualization of the cystic duct. The cystic duct should be partially divided, probed and ligated before proceeding to ligate the cystic vessels. These should be secured at a point distal to the division of the cystic duct, and thus even farther away from the danger zone of Calot's triangle. Injuries to the hepatic duct seem to occur more commonly while securing the vessels than when dividing the cystic duct. The passage of ligatures on needles is especially dangerous. An aneurysm needle or a Deschamps' ligature carrier is much more likely to follow the normal planes of cleavage.

When removing a gallbladder from above downward, it is important to remember that the left or mesial aspect of the organ is much shorter than the right. Failure to remember this may bring the operator much nearer to the hepatic duct than he realizes, if his guiding points are the ampulla of the gallbladder and the free edge of the gastrohepatic ligament. In cases of acute gangrenous cholecystitis, undue traction must not be exerted upon the clamp holding the gallbladder, as the organ can be easily torn away at its junction with the cystic duct. It is probably wiser to leave a small area of the ampulla in gangrenous conditions because duct injuries are not so liable to occur in attempts to control hemorrhage.

The presence of a biliary cirrhosis giving rise to jaundice may lead to secondary operations when in fact the icterus is the result of the cirrhosis rather than obstruction from a reformed stricture.

Wound Dehiscence and Evisceration.—These unwarranted complications were the primary cause of death in three cases, twice from the effects of a

pronounced ileus and once from a peritonitis. The operations were performed under inhalation anesthesia for chronic cholecystitis and cholelithiasis through an upper right rectus muscle splitting incision. In two instances the operator recorded excessive difficulties in effecting a closure of the abdominal wound. Symptoms of shock with abdominal distention and vomiting appeared within 48 hours in two cases. Acute dilatation of the stomach was suspected but it was not until the third day that the symptoms were explained by the appearance of an external evisceration. The stomach presented in the dehisced wound in two cases. In one instance a thrombosis of the gastric vessels and a severe ulcerative gastritis was present, probably as a result of an incarceration of the stomach in the wound.

In addition to these there were two cases in which evisceration was secondary to peritonitis with pronounced distention. It also occurred once following a violent coughing spell in a patient dying from suppurative cholangeitis with liver and subphrenic abscesses.

As was noted above, the operations in which evisceration occurred, were all performed under general anesthesia. The greater ease and security of closure under spinal anesthesia should make this complication less common.

The symptoms of ileus should make one suspicious of a wound dehiscence, as paralytic ileus due to extensive small intestinal manipulations or mechanical intestinal obstruction is quite rare in gallbladder surgery.

Pneumonia.—This was designated as a cause of death only when autopsy failed to reveal other significant lesions. If a postmortem examination, for example, disclosed either a cholangeitis, a subphrenic abscess, or an ileus, and, in addition, evidences of pneumonia, the latter was disregarded as the determining factor in the fatal outcome. Pneumonia on this basis was responsible for 11 deaths, seven of 46 deaths following operations upon the gallbladder, and four of 31 in which the common duct was opened. Approximately one-sixth of the deaths following operation for inflammatory and calculus diseases of the biliary tract were thus due to acute pneumonitis. The factors predisposing to the fatal respiratory complications in this series might be listed as chronic bronchitis and a history of an old pleurisy each once, unusual obesity in two cases, and advanced age in two instances. The diagnoses were very evident clinically in all but two cases in which a fulminating pneumonia was not even suspected before postmortem.

The prevention of this complication still taxes the ingenuity of the profession. The present study shed but little light on its prophylaxis. The question of anesthesia in cholecystectomy is of great importance. Four of the seven inhalation anesthesia deaths occurred in an older age group, the three other patients were young, healthy and vigorous. All of the four patients in the spinal group were over 60, two being over 70. It is generally conceded that the type of anesthesia will probably have little effect on the incidence of pneumonia in older people. However, in this small group, it

would appear that spinal anesthesia in the young and vigorous is less apt to be followed by fatal pulmonary complications.

All deaths following inhalation anesthesia were due to bronchopneumonia of various types and degrees. Necrotizing bronchitis with bronchopneumonia similar to the influenza type was present in a number of cases. Multiple abscess formation occurred in one case, a gangrenous pneumonitis in another and an empyema in a third.

The pneumonia following spinal anesthesia appeared to have a different pathogenesis for only one out of the four was of bronchopneumonic type. It was lobar in one case and in two the pneumonic process was engrafted upon a bilateral atelectasis involving both lower lobes. This atelectasis was possibly dependent upon the paresis of the diaphragm incident to spinal anesthesia. This may have been aided by the weight of the abdominal viscera pressing against this muscle while the patient was kept in shock position immediately postoperatively. It might be a better procedure to eliminate this position following spinal anesthesia unless it is distinctly indicated.

Cardiac Failure and Pulmonary Embolism.—Three deaths were due to heart failure. Each exemplifies a type of problem with which the surgeon is confronted. The presence of cardiac damage was known in one, but this had to be disregarded in the face of extending infection. A simple cholecystostomy was performed under spinal anesthesia, progressive cyanosis and dyspnea followed, with death in 72 hours. Postmortem examination showed coronary arteriosclerosis with myocardial degeneration. In another, symptoms due to sudden cardiac decompensation with acute and chronic passive congestion of the liver were mistakenly interpreted as of gallbladder origin. The circulatory edema of the gallbladder was mistaken as inflammatory and a cholecystectomy was performed. The patient died of progressive heart failure. In the third the patient was abnormally obese but presented no preoperative evidence of organic heart disease. The heart, however, proved to be incapable of sustaining the increased burden necessitated by a cholecystectomy and choledochostomy for common duct stone. The postoperative course was afebrile and bile drained freely. There were a number of attacks of weakness with small pulse, which were thought to be due to either pulmonary embolus or cardiac failure. Sudden death occurred with signs of pulmonary edema of the lungs on the thirteenth day. Postmortem showed extensive myocardial degeneration and pulmonary edema. This latter type of death would probably be more frequent if very obese individuals were indiscriminately operated upon. It is now customary to refer these patients to the metabolic clinic for reduction. The fact that cardiovascular disease, especially closures of the coronary artery, may closely simulate attacks of biliary colic or even of acute cholecystitis must constantly be borne in mind. Whatever the arguments may be for immediate intervention in clear cut cases of acute cholecystitis, in doubtful cases of suspected organic heart disease the best interests of the patient will probably be served by a conservative attitude until the situation becomes clearer. On the other hand, the symp-

toms of patients with cholelithiasis and cholecystitis are often interpreted as being due to coronary artery disease, especially when minor electrocardiographic changes are present. The matter is still further complicated by the fact that both of these conditions frequently occur together. Here the cooperation of surgeon and internist in evaluating the importance of both symptoms is of the greatest moment.

Pulmonary embolus accounted for two deaths. In one of these there was a totally uneventful convalescence until sudden death occurred on the ninth postoperative day. In the other case there were two attacks of precordial pain and dyspnea, which were apparently interpreted as being of cardiac origin. On the fifteenth day there was sudden death from an embolus lodging in the main branch of the pulmonary artery.

TABLE III

CAUSES OF DEATH IN INSTANCES OF CHRONIC CHOLECYSTITIS

Cause	Number
Peritonitis, diffuse	5
Retroperitoneal phlegmon	1
Duct injuries	2
Evisceration	3
Pneumonia	5
Pulmonary emboli	2
Enterocolitis	1
Intestinal obstruction due to stone	2
Sepsis	1
Cardiac	1
Pancreatitis	2
	25

Uremia and the "Hepatorenal Syndrome?".—The cases which clinically manifested the uremic syndrome fall into two groups. In the first group, consisting of two patients, there was definite preoperative evidence of renal impairment, the postoperative course was characterized by an increasing azotemia, and the postmortem findings in the kidney were those associated with chronic nephritis and the arteriosclerotic kidney. In other words, this group consisted of patients whose diminished kidney function, due to definite anatomico-pathologic changes proved unequal to the increased burden thrown upon them by biliary infection and operation. It would be difficult to maintain that these pathologic changes were secondary to hepatic damage resulting from biliary tract disease. As a matter of fact, in one of these cases the disease was limited solely to the gallbladder, the ducts not being involved. Similar pathologic renal changes with a like postoperative course have been found in too wide a diversity of surgical conditions to permit of the view that the kidney alterations are specifically hepatic in nature.

In the second group were those cases which preoperatively showed no evidence of kidney disease but which following operation presented azotemia and clinically manifested symptoms resembling those of uremia. The symp-

toms encountered in this group have often been attributed to an "hepatorenal" syndrome. This group of ten cases may again be subdivided into those in which autopsy disclosed a definite anatomic cause for death, and those in which it did not. Seven cases fell into the former group, and in them either infective or suppurative processes sufficient to account for death were found. These were respectively (1) peritonitis, (2) diffuse confluent virulent bronchopneumonia, (3 and 4) suppurative pylephlebitis in two cases, (5) suppurative pancreatitis, (6) suppurative cholangeitis, and (7) sepsis together with arsenic poisoning in the seventh case. In order to illustrate the manner in which clinical phenomena may be misinterpreted a very brief résumé of Cases 6 and 7 might be of interest.

Case 6 was that of a woman, age 30, who was operated upon for common duct stones and a virulent cholangeitis. The temperature was normal after the first week. However, she always appeared somewhat shocked and her skin was cold and clammy. She received three transfusions with but little effect. During the third week postoperatively, the urine became bloody and scant, and there was a rise in the blood urea. She became irrational and died on the seventeenth postoperative day. Postmortem examination showed liver abscesses, subphrenic abscesses and a gangrenous cystitis, the latter finding explaining the hematuria.

Case 7 manifested the most classic clinical and pathologic evidences of hepatorenal insufficiency. Anuria supervened two days after the onset of symptoms and lasted for five days, with a steady rise in the blood urea to 180. The bilirubinemia simultaneously increased until the van den Bergh was 4.5 mg., and then receded concomitantly with a fall in the blood urea, and the secretion of urine. Finally both blood figures reached normal. The patient appeared to have been well on the way to spontaneous recovery when she developed a severe suppurative parotitis with a resultant Staphylococcus aureus sepsis. Autopsy disclosed a subsiding acute cholecystitis and cholangeitis without common duct stones, hepatic degeneration with necrosis (the type found in bacteremia), and marked focal degenerative changes in the kidneys, bacterial in origin. This case might easily have been interpreted as a typical case of hepatorenal syndrome induced by an acute infection of the gallbladder. Two complicating factors in this instance were that arsenic was found in the urine on one occasion, and that a bacteremia was present which may have caused the pathologic changes in the liver and kidney present at postmortem. The significance of the arsenic is difficult to evaluate. It can produce a clinical picture simulating the above. The sepsis further complicates matters for the focal necrotic changes in the liver could be, and probably were, accounted for by bacterial metastasis.

It is obvious that in these seven cases the so called "uremic" picture was secondary.

Three cases, however, remained which presented, at autopsy, neither chronic nephritic changes nor any obvious cause for death. These patients were all over 55 years of age. The jaundice was not marked. The operative

findings were those of long standing disease apparently much longer than the history would indicate. The common and hepatic ducts were greatly distended and contained numerous stones but the obstruction remained incomplete. Their course following operation was characterized by sluggishness, asthenia, gradual deterioration, stupor and coma. The urinary output was diminished and the blood urea which rose to 105, 76 and 39 mg., respectively, in these three cases later fell to lower figures following the intravenous administration of sodium chloride and glucose. They did not, however, reach normal. It is important to note that there was no increased icterus paralleling the rise in the blood urea. Furthermore, the external drainage of bile continued freely in these cases. A phenomenon present in all these cases was a persistently low blood pressure which some thought was a factor in the production of the azotemia. Death ensued in 10, 14 and 60 days following operation, in the last case one month following a recrudescence of fever and reopening of a biliary fistula due to a retained stone in the common duct. Postmortem examination failed to reveal any marked or unusual degenerative changes in the liver in any of these cases. The changes in the kidney were not striking, and in one instance only were they enlarged as the result of the edema of the glandular and interstitial tissues.

However, it must be remembered that the clinical picture and azotemia present in the so called "hepatorenal syndrome" which occurred in the last mentioned three cases, are not confined solely to diseases of the biliary tract or liver. Extrarenal azotemia, with a similar clinical picture, is found in other surgical conditions such as traumatic shock, postoperative collapse, intestinal obstruction, extensive burns and some acute fulminating infections, especially those caused by the Clostridium welchii. Fishberg states that "the pathogenic circumstance common to all these states is a deficient venous return to the heart which is most often the result of a decrease in the circulating blood volume. The decrease in the venous return entails an equal diminution in cardiac output which probably reflexly causes peripheral vasoconstriction. The vasoconstriction includes the kidneys, and the consequent diminution in the renal blood flow results in azotemia which may be abetted by heightened destruction of protein with an attendant increase in the quantity of nitrogenous end products to be eliminated."

"Liver Shock" Deaths.—In a discussion of the causes of death following gallbladder operations, the question of the so called "liver shock" deaths calls for consideration. These cases have been defined as those in which following a simple cholecystectomy there is a rapid development of hyperpyrexia with signs of either collapse or delirium, or stupor terminating usually in death within 48 hours. A clinical study of cases of this type has recently been reported in detail by Touroff, who used as a basis of investigation the cases of gallbladder diseases operated upon at The Mount Sinai Hospital during the past ten years. His conclusions are paralleled by those reached in this study of postmortem material. There were no instances of this clinical syndrome in which an autopsy failed to establish a well defined

anatomic cause of death. In all three cases the development of this high temperature syndrome led to a tentative clinical diagnosis of "liver shock" death. The following causes for death, however, were established by autopsy in these three instances. Case 1. Subphrenic peritonitis with beginning abscess formation due to Streptococcus hemolyticus. Case 2. Subphrenic and subhepatic biliary extravasation. Case 3. Fulminating, diffuse necrotizing bronchopneumonia of the influenza type.

There was another case similar to the above except that an incidental common duct stone was removed by choledochotomy. The patient was an obese woman of 60. The operation was prolonged, and during its course the colon was accidentally injured. B. coli and B. Friedländer were cultured from the gallbladder bile. There was no immediate shock but the temperature rapidly rose to 105.8° F. with fatal issue in 18 hours. The only findings at autopsy were an acute gastric dilatation with erosions and degenerative changes in the liver. The findings were insufficient to account for the patient's death. However, it would seem that exitus was due to postoperative shock rather than a specific failure of the function of the liver.

GROUP II-B.—*Primary Hepatic Degeneration (Subacute Yellow Atrophy)—Biliary Cirrhosis—Noncalculus Cholangeitis.*—Differential diagnosis between jaundice due to disease of the extrahepatic biliary ducts and that of intrahepatic origin is at times exceedingly difficult. There were seven instances in which failure to distinguish between the two led to the performance of futile operations. The surgical procedures, however, were not the causes of the mortality in five cases. These patients ultimately died from the uninterrupted progress of the disease from which they were originally suffering.

Autopsy unexpectedly revealed in three cases that death which followed cholecystogastrostomy for jaundice supposedly of an obstructive nature, was due to a primary hepatic degeneration, so called subacute yellow atrophy. These cases have been carefully reviewed with the idea of determining whether anything could have been done to have avoided these unnecessary operations. One point immediately became apparent, *i.e.*, that all these cases clinically presented a constant or slightly increasing jaundice with the simultaneous presence of bile in the stool. This combination usually does not portray a surgical condition of the extrahepatic bile ducts. While it is conceivable that this combination of symptoms might occur either with a calculus cholangeitis or a slowly growing carcinoma of the papilla, it certainly does not happen in cases of carcinoma of the head of the pancreas. The latter diagnosis was the one made at operation in all these cases by palpation of the pancreas and duodenum. In one instance the well known difficulty of pancreatic palpation was further complicated by the induration produced in the head of the viscus by the penetration of an ulcer of the posterior duodenal wall. But even here the operation of cholecystogastrostomy would probably have been avoided, had it been borne in mind that bile was present in the stool and urobilin in the urine. One of these patients became comatose two days following operation and died on the fourth day, and the other

two developed a septic type of temperature which led to the suspicion of subphrenic abscess. Autopsy revealed the classic picture of subacute yellow atrophy with degeneration. There were no abnormalities in the extrahepatic ducts and bile was found to be present in the common duct.

There were also two cases of biliary cirrhosis in which the operation was really exploratory in character. The presence of hepatic disease was recognized at operation which was limited in each instance to the performance of a biopsy and a cholecystostomy. One of these patients died within one week from hemorrhage. The other left the hospital and returned two years later to die from a gradual exacerbation of the disease.

In addition to the above cases, there were two cases of subacute cholangeitis without fever and without stones in which surgical intervention was probably not indicated. Even after reviewing these cases it is difficult to see how these errors could well have been avoided. The history in both instances was typical of biliary colic, and while the patients had bile in the stool, the icterus on the other hand was only very slight. Operation in one instance was limited to an exploratory laparotomy; in the other a cholecystectomy and choledochostomy were performed. Judging from the autopsy findings these patients would probably have made a temporary, if not permanent recovery from their illness. Death in one instance was due to a peritonitis and in the other to a severe bronchopneumonia.

TABLE IV

CAUSES OF DEATH IN CASES OPERATED UPON WITH INCORRECT DIAGNOSES

Cause	Number
Biliary cirrhosis	2
Primary cholangeitis	2
Subacute yellow atrophy	3
	7

GROUP III.—*Carcinoma of the Biliary Tract.*—The mortality in this group has been extremely high. It has limited the radical surgical approach to neoplasms of the biliary tract until relatively recently. Operations have usually been confined either to exploration in order to rule out the possibility of calculi, or to palliative procedures. Lately the operative technic advocated by Whipple and Parsons in cases of carcinoma of the papillary region of the duodenum has stimulated new interest and hope in this field. This is partially warranted by the incidence of metastases found at postmortem in this and other reported series.

Operation was performed in four cases of carcinoma of the papilla. A transduodenal local excision of the tumor was performed in combination with a cholecystostomy in two of these. One of the patients died of a retroperitoneal phlegmon, the other from repeated intestinal hemorrhages. In the remaining two cases in which a cholecystogastrostomy was performed, the autopsy revealed that the neoplasm could have been removed by the

technic of Whipple and Parsons. Furthermore, no evidence of metastases was found in any of these four cases. In a recent nonoperated case of carcinoma of the papilla which died of suppurative cholangeitis, no evidences of metastases were found.

Failure to recognize small carcinomata in the infraduodenal portion of the duct or pancreas may lead to perplexing difficulties following biliary tract operations. Fistulae or cholangeitis may lead to multiple futile operations. Two such cases were finally solved at postmortem. A brief reconstruction of them might prove instructive. Cholelithiasis was absent and obstructive jaundice present in both cases at operation. A cholecystectomy with choledochal drainage was performed. The above combination of circumstances should certainly have contraindicated cholecystectomy as removal of the gallbladder enormously complicates the possibility of short circuiting the biliary flow above a possible obstruction developing subsequently. If, clinically, the jaundice has been obstructive and progressive, and at operation the duct appears dilated but thin walled, an incision should be made in the supraduodenal portion of the common duct as far from the junction of the cystic duct as possible. If exploration reveals no stone in the duct, the incision may be closed or drainage instituted. If a stricture or tumor is suspected, the duct may be ligated and divided and a cholecystogastrostomy performed. Judging from the findings in one of the cases, a specimen for pathologic examination could have been obtained from the distal portion of the choledochus by the use of a small curette. One further point merits mention. It is easily understandable that in the absence of positive evidence of carcinoma, one would be loath to proceed with a radical operation beyond a cholecystogastrostomy. Under these circumstances, the hope is assured that the obstruction is due to chronic pancreatitis. It should be emphasized that in this postmortem series, chronic pancreatitis was never by itself the cause of sufficient encroachment upon the common duct to cause an obstructive jaundice of any severe degree.

The presence of an acute suppurative cholangeitis without stones should arouse suspicions of an obstruction due to carcinoma low in the choledochus. Five such cases were encountered in this series.

Considerable differential diagnostic difficulty may be encountered in those cases in which a carcinoma of the duct develops at some period subsequent to the performance of a cholecystectomy. Three such cases were encountered at postmortem. The gallbladder had been removed six months, two years and nine years previously, respectively. The hepatic duct was the site of the lesion in all these cases.

Differentiation from an inflammatory lesion could have been made by the fact that the involvement of the duct was tubular, and extended for about one to one and one-half inches whereas an injury usually results in a narrowed annular stricture. Furthermore, the duct distal to the malignant obstruction could easily be traced to the site of constriction and without any loss of continuity. An accurate diagnosis may be obtained by removal of

a specimen. A similar difficulty may arise in which a chronic cholecystitis with stones is complicated by a stricturing lesion in the common duct near the junction of the cystic duct. The strictures which were thought to be inflammatory in two such instances proved to be scirrhous carcinomata infiltrating along the cystic duct.

Carcinoma of the pancreas and gallbladder presenting symptoms which led to operation, were far less favorable surgically because of distant metastases. This difference is probably not occasioned by any variation in malignancy between these and duct carcinomata, but rather due to the lapse of time before symptoms became evident. Carcinoma of the ducts and papilla, because of the obstruction which they soon produce, inevitably give rise to jaundice early. Neoplasms of the gallbladder, and those tumors of the pancreas which do not originate in immediate juxtaposition to the duct, may remain silent for a considerable time during which widespread dissemination may occur. Postmortem examinations of operated cases of pancreatic carcinomata revealed widespread metatases to the regional lymph nodes and the liver in five instances. In two other cases in which no metastases were found, the carcinoma of the pancreas had developed adjacent to the common duct with early compression and invasion. A radical removal might have been feasible in these two cases had the pathology been recognized at operation.

Widespread metastases were found in seven of nine cases dying following operation for carcinoma of the gallbladder. In two cases without metastases, early operation had been forced in one instance by a pericholecystic abscess, and in the other by an infiltration of the common duct. Two patients had refused cholecystectomy for stone two years before their final and fatal operation and another had been subjected to an appendectomy for symptoms which were undoubtedly of gallbladder origin. The prognosis in carcinoma of the gallbladder would appear poor except in those cases fortunately operated upon for cholelithiasis in which a fundal carcinoma was incidentally removed.

TABLE V

CAUSES OF DEATH IN CASES OPERATED UPON WHICH HAD CARCINOMA

Cause	Number
Hemorrhage	9
Carcinoma and unrelieved jaundice	5
Suppurative cholangeitis	5
Peritonitis	4
Duodenal fistula	1
Lobar pneumonia	1
Pulmonary embolus	1
Acute pancreatitis	1
Meningitis	1
	28

SUMMARY.—The causes of death in 130 autopsies occurring in surgical diseases of the biliary tract are analyzed. These are arbitrarily divided into three groups.

Group I comprises those upon whom postmortem examinations were performed, in which the disease process and its complications were found to be the eventual causes of death. Suppurative cholangeitis accounted for death in 16 cases. This dreaded complication, the result of prolonged incomplete obstruction and low grade infection, ended either in multiple hepatic abscesses with or without perforation, portal or hepatic suppurative phlebitis, general sepsis or cholangeitic hepatitis. The postmortem findings vividly represent the final result of years of operative delay, due either to lay ignorance or medical indifference to the excellent results derived from early surgical intervention. On the other hand, the importance of operative therapy in obstructive jaundice is, fortunately, fast being recognized. This is mirrored in the present study by the relatively few deaths from hemorrhage, only three, and the other manifestations of a prolonged obstructive jaundice, *i.e.*, death from the effects of an unrelieved jaundice and a biliary cirrhosis. The dangers inherent in a long standing biliary duct infection with "silent stones" (unfortunately not manifesting their presence by persistent clinical jaundice) have not as yet been sufficiently appreciated. This fact is reflected in this series by the high incidence of death due to cholangeitic infection.

Suppurative pylephlebitis, the most fatal complication of a widespread and severe infection, was the cause of death in six cases of acute cholecystitis and in two cases of calculus cholangeitis, and contributory in five cases. When once this complication, with its multiple pylephlebitic abscesses has developed, very little can be done, and death is invariably a foregone conclusion.

Diffuse peritonitis due either to perforation of the gallbladder into the free peritoneal cavity, a rupture of a pericholecystitic abscess, or a "durchwanderung" infection complicating acute cholecystitis, accounted for nine deaths. This represents about one-third of the anatomic causes of death occurring in acute cholecystitis. However, the fact that this complication affected patients of advanced years is to be noted.

Group II-A is composed of the "interval" cases in which the disease at the time of operation was not threatening to life, and in which the lethal outcome could be traced either to errors in judgment or technic, or to those operative complications which at the present stage of surgical development seem to be almost unavoidable.

Diffuse peritonitis due to biliary extravasation, operative injury to viscera adjacent to the gallbladder or the exacerbation of a latent cholecystic infection, accounted for 13 deaths. Ten deaths were ascribed either directly to immediate operative injuries or subsequent traumatic strictures of the extrahepatic bile ducts. These fatalities, approximately 10 per cent of all deaths in benign cases, are a serious reflection upon surgery because they are directly attributable to technical mistakes which probably could have been avoided had greater operative care been exercised.

Wound dehiscence, an almost unwarranted complication, caused death in three cases. Hemorrhage due to technical failure to secure the cystic artery or control bleeding from the liver bed was not encountered in this series. Two deaths were due to uremia, with autopsy evidence of chronic nephritis. (There were seven cases presenting a clinical picture resembling uremia in which definite extrarenal anatomic causes for death were found.) Three cases presented a clinical picture resembling uremia but without definite renal changes evident at postmortem. These cases are frequently designated as hepatorenal insufficiency. They showed, however, no parallelism between the degree of jaundice and the diminution of renal function. Furthermore, neither extensive degenerative renal or hepatic changes were found at autopsy. Pneumonia, in spite of all efforts directed to its prophylaxis in recent years, accounted for 11 deaths, 11 per cent of the deaths coming to autopsy. Three deaths were due to heart failure, and two to pulmonary embolism. No cases of "liver shock" were encountered following cholecystectomy.

Group II-B is composed of autopsies obtained in those cases which were operated upon with a tentative diagnosis of gallbladder disease but in which neither operation nor postmortem findings verified the diagnosis. These cases consisted of subacute yellow atrophy of the liver, nonsuppurative cholangeitis (cholangeitis lenta), and biliary cirrhosis, and were undoubtedly confusing clinically. A more careful preoperative evaluation of symptoms and findings might have avoided a few unnecessary surgical mortalities.

Group III, comprising the carcinomata of the biliary tract, consists of 28 cases. Autopsy failed to disclose the presence of visible gross metastases in the majority of malignant lesions involving the papilla and extrahepatic bile ducts. These findings emphasize the fact that these malignant lesions are worthy of an attempt at radical extirpation. The presence of fatal hemorrhage as a cause for death in these cases after a relatively minor surgical procedure emphasizes the wisdom of stage operations if the radical approach is contemplated.

DISCUSSION OF THE PAPERS OF DOCTORS HEYD AND COLP

DISCUSSION.—HENRY W. CAVE, M.D. (New York), confined his discussion principally to Doctor Heyd's paper, which he considered a most painstaking and critical analysis of the author's experiences in 557 operations upon the gallbladder and extrahepatic biliary passages.

In a series of 500 noncomplicated cholecystectomies, he noted that Doctor Heyd reported a notably low mortality rate of 3.3 per cent, while in 34 cases of choleycstostomy for acute cholecystitis, there were five deaths, a mortality of 14.7 per cent. These mortality statistics appear in keeping with other similar series, in other hospitals, and again emphasize that too long delayed operation, with its accompanying occasional perforation and severe infection, adds to the death rate and demands drainage rather than removal of the gallbladder in this latter desperately sick group.

Regarding pulmonary complications, Doctor Cave stressed the fact that pneumonia, formerly feared and considered the most common postoperative complication, has to some extent been prevented by the use of avertin, nitrous

oxide, ethylene, or cyclopropane anesthetic combinations, ether seldom being necessary. Spinal anesthesia, he said, is not devoid of postoperative sequelae such as massive atelectasis and pneumonia. Hyperventilation of the lungs with carbon dioxide and oxygen at the close of the operation and at intervals for the following 24 hours tends to lower the incidence of pulmonary complications.

Hemorrhage at the time of operation, or immediately thereafter, may be caused by division of an anomalous vessel or from a friable cystic artery which may be cut through by the ligature, or, thirdly, from injury of the portal vein or the hepatic artery in an attempt to clamp the cystic artery which may have slipped away. Finally, there may be profuse bleeding from the gallbladder sulcus. The transfusion of whole blood prior to, and immediately after, operation will diminish uncontrolled capillary bleeding in patients with severe obstructive jaundice and is far superior to the use, in whatever amounts, of calcium lactate.

Accurate anatomic dissection with proper exposure through a sufficiently long incision; the removal of the gallbladder from above downward, with identification and separate ligation of the cystic artery before the cystic duct is clamped or tied, leaving a flange of the serosal surface of the gallbladder wall to close over the gallbladder sulcus, will not only diminish considerably the danger of hemorrhage but the danger from kinking and injury to the common bile duct.

Holman has demonstrated that anomalous branches of the hepatic ducts not only may be present, but if cut, during the course of a cholecystectomy, may be the source of an immediate and, at times, prolonged and distressing biliary drainage; moreover, small biliary passages may be opened, especially if much liver tissue has been traumatized. These two facts alone, he thought, are of sufficient importance to demand drainage after all cholecystectomy operations, thus practically doing away with that infrequent yet possible death from bile peritonitis. Although he had closed 20 per cent of his cholecystectomy cases, without drainage, without a fatality, he nevertheless was convinced that drainage should be instituted in all fairness to the patient.

Concerning that enigma, "liver deaths," about which there is very little substantial knowledge, Doctor Cave recalled three deaths within 40 hours following cholecystectomy, reported from Roosevelt Hospital in 1926. These were classified as so called "liver deaths" and it was believed that these fatalities were due to absorption of toxins from chemically impaired liver cells or infected bile from the intrahepatic biliary passages. Whatever the actual cause of death in this baffling group of patients, he felt that with the abundant use of sugar by mouth and glucose intravenously before and after operation, these unfortunate catastrophes might be eliminated.

Infection of the lesser peritoneal cavity in the cases of acutely inflamed gallbladder can be avoided by the use of a folded gauze Mikulicz pad placed snugly in the foramen of Winslow, as suggested by Lahey.

Incisional hernia, which occurs all too frequently, must be considered a late complication of gallbladder surgery. It is especially prone to follow drained, acutely inflamed gallbladder cases or prolonged drainage of the common duct, but stab wound drainage in the flank also occasionally results in herniation. In a series of follow up notes on 100 operated cases of gallbladder disease at the Roosevelt Hospital, surveyed recently, the amazing discovery was made that there were 12 incisional herniae, all of which had occurred in cases where catgut had been used, and he wished to be emphatic in stating that the use of silk throughout in right upper quadrant wounds in the nongrossly infected cases is important if the incidence of incisional hernia is to be diminished.

Dr. Allen O. Whipple (New York) remarked that one seldom had the opportunity to review such a large number of autopsy studies, in an individual group, as had been presented by Doctor Colp. Autopsy records are always enlightening in that they point unmistakable lessons. In going over the various causes of death in these cases, certain factors stood out. In regard to biliary peritonitis, however, one exceedingly important point was not mentioned. He had learned a lesson from a rather serious peritonitis that had resulted from a mistake, the possibility of which is not mentioned in either text-books or articles, namely, the tendency in the operating room, after the common duct drain has been inserted and sutured onto the common duct, and the drain brought out, to clamp off the tube so that it will not soil the dressings. The patient is then sent down to the ward, and unless very definite instructions are left to have the clamp removed immediately, so that the bile flow may be restored, there is excellent chance of bile leakage, sometimes of a very infectious character, into the peritonal cavity, during the first ensuing two or three hours. In one of the three cases at Presbyterian Hospital where this occurred, fatal peritonitis developed. The intern staff, in fact all of the staff, should be impressed with the urgency of not having the common duct drain clamped off when the patient is taken down from the operating room.

In regard to common duct stricture, Doctor Whipple emphasized one point particularly, namely, when an anomaly is found either in the vessels or in the ducts, the greatest care should be exercised to avoid damage to other anomalous structures. He had only a few days previously operated upon a patient with an aberrant hepatic artery running anterior to the common duct; that is, there was an anomalous duct system as well as the anomalous vascular system. Doctor Whipple stressed the fact that if a duct has been injured, the time to repair it is *immediately*. The repair, if done at the time of injury, is incomparably easier and the results infinitely better, particularly if the duct has been cut.

Regarding the possibility of carcinoma of the papilla of Vater being present in cases of deep jaundice not associated with stone, he particularly concurred in Doctor Colp's emphasis of the diagnosis of carcinoma where there is no associated stone. He also stressed the fact that no attempt should be made to remove a carcinoma of the papilla in one stage. These patients will not stand an extensive operation when they are deeply jaundiced, and if any attempt is made to excise the tumor through the duodenum there is very great risk of hemorrhage or of duodenal fistula because of the failure of tissues to unite properly with the patient in the condition he is in at that time. The operation, if it must be performed, should be carried out in two stages, and it is most essential to make a large opening between the gallbladder and the stomach if the operation is done in two stages with the idea of resecting the duodenum. The only late unfavorable result in Doctor Whipple's experience had been the tendency for cholangeitis to occur because of the narrowing of the opening between the gallbladder and the stomach. Therefore, the opening must be sufficiently large to avoid cholangeitis.

Dr. Henry F. Graham (Brooklyn, N. Y.) reviewed the causes of death in gallbladder inflammations and stated that careful analysis would show that practically all are due to delay, assuming competent surgical care. This delay is threefold: (1) On the part of individuals affected; (2) the medical profession, including the gastro-enterologists; and (3) on the part of surgeons, after the patient has entered the hospital.

The surgeon's policy of watchful waiting has encouraged the entire medi-

cal profession to believe that to watch and delay operation in cases of acute cholecystitis is all right. They reason, logically, that the patient might just as well be watched at home as in the hospital. Goldish and Gillespie have shown that the average age of those who died after operation was ten years more than that of those who lived, which is an indication, at least, that their disease had lasted longer.

Touraff reported 75 cases of proven acute cholecystitis from Mt. Sinai Hospital that had been operated upon during the "resting" period following an acute attack. In 24 cases—or nearly one-third—pus or gangrene was present at the time of operation—a poor advertisement for watchful waiting. Repeated attacks of pain and vomiting cause inanition, diminished resistance to infection, and a feeble heart muscle. Liver function is inhibited or destroyed.

An analysis of the last ten deaths in 135 cases (6.6 per cent mortality) on the speaker's service at the Methodist Hospital showed that the common duct had to be drained in five, or 50 per cent of cases. In four, stones were present in the common duct. There were: one perforated, three gangrenous, and one suppurative gallbladder, and one abscess outside the gallbladder with a concomitant pancreatitis. Delay was evident in all of these. There was only *one* death from *pneumonia*—in a case of gangrenous gallbladder, and there was one cardiac thrombus, also with a gangrenous gallbladder.

Doctor Graham cited one case in particular to illustrate the danger of delay. This man had suffered pain for four months before coming to the hospital, had lost 30 pounds in weight, and had had repeated attacks of jaundice. A contracted gallbladder containing stones was removed, the common duct explored, and the wound drained. Inanition continued. One month after operation the wound burst open and he died 24 hours later. Autopsies on two other cases showed multiple abscesses with a pelvic abscess in each instance, while a third case showed an area of liver necrosis near the gallbladder bed.

The speaker wished to make a strong plea for a crusade to urge: Prompt operation in an early attack of cholecystitis, prompt reference of cases of acute cholecystitis or exacerbations of chronic cholecystitis to the surgeon, and prompt operation by the surgeon. Prompt operation implied education of the general public, the profession and the gastro-enterologists. He had recently removed a gallbladder two weeks after a woman had given birth to a baby. More than 100 stones were present. Yet her first attack had occurred four months before the operation! If such a campaign were initiated, it would unquestionably result in a marked improvement in gallbladder mortality.

Dr. George J. Heuer (New York) had recently been studying cases of acute cholecystitis at the New York Hospital, and thought it seemed advisable to consider the disease as a specific condition in the sense that it should not be included in the general run of gallbladder cases; and to determine whether the prevailing opinion that it was wiser to wait for the acute attack to subside before subjecting the patient to operation was justified by the results obtained. A study of the cases of acute cholecystitis at the Cincinnati General Hospital showed: (1) That it is often impossible from the symptoms, physical signs and laboratory data to predict the course of the pathologic process in the gallbladder. The attack may subside, it may proceed to gangrene and perforation of the gallbladder even in the presence of subsiding symptoms; (2) That if acute cholecystitis is considered as a disease by itself, the incidence of gangrene and perforation is quite high and occurs in about 20 per cent of the cases; (3) The mortality following operation in-

creases greatly as a result of gangrene and perforation, and represents from 10 to 20 per cent of the total mortality in the general run of gallbladder cases. In Doctor Colp's series at Mt. Sinai Hospital it represented 33 per cent. This situation suggests that encountered of acute appendicitis, a disease which for some time was considered safer to treat surgically in an "interval," *i.e.*, after the acute attack has subsided.

A further study of 126 cases of acute cholecystitis at the New York Hospital leads to findings, in general, similar to those in Cincinnati. In 125 cases, 32 or 25 per cent had at operation gangrene or gangrene and perforation of the gallbladder. Our attitude toward operation in this series of cases was to operate earlier in the disease in order to prevent the mortality due to gangrene and perforation. In over 65 per cent of the cases, therefore, operation was performed the day of admission. The results show that in 125 cases there were four deaths, an operative mortality of 3.2 per cent. Analyzed from the viewpoint of the extent of the disease, there were 112 cases of acute cholecystitis without demonstrable perforation of the gallbladder with two deaths, a mortality of 1.8 per cent; and 13 cases with perforation of the gallbladder, extracholecystic abscess (12) and generalized peritonitis (1) with two deaths, a mortality of 15.3 per cent. From these observations it would appear that the dangers of operation in the acute stage of acute cholecystitis have been overemphasized and that operation before gangrene and perforation have occurred is helpful in reducing the mortality in acute cholecystitis.

Dr. Howard Lilienthal (New York) recalled that 32 years ago he was the first one in America to publish a series of gallbladder operations. There were 42 cases of cholecystectomy, unselected, one of whom was a woman six months pregnant and suffering from acute Streptococcic sepsis. This case was the only mortality (2.3 per cent—an unusually fine record even now). He developed a method at the time which came to be known by his name, and asked Doctor Colp if he would not state, in closing, whether it is still being used; *i.e.*, the gallbladder is dissected free until the neck is reached, then two sutures of chromicized catgut are put round the neck of the gallbladder, but not tied; they are used as traction ligatures to cut off the gallbladder without constricting it. Utilization of this method makes it possible to see exactly what bleeds and to care for it. The gallbladder bridge was at first used; now the broken table. Sometimes bleeding is noted after the angulation of the table has been straightened. If so, it should be raised again and the vessel caught.

With regard to pylephlebitic abscess, which Doctor Cave intimated to be a hopeless condition, Doctor Lilienthal felt that although it is generally hopeless, nevertheless it is not completely so. He reviewed a case he reported before the New York Surgical Society a good many years ago, a patient upon whom he operated for an acute condition of the gallbladder accompanied by stones, and in whom he found several fairly good sized hepatic abscesses, *i.e.*, the size of a small English walnut. He opened four or five of them, but did not make any attempt to do more. He thought the man would die, but, on the contrary, not only did he get well but he returned a year later to have his gallbladder removed. This was effected and the scar of one of the abscesses that had been incised at the first operation was resected, which, when examined, was found to consist of bile pigment and fibrous tissue. There were multiple healed abscesses at that time. In any similar case that he might encounter, he said he would not say, "This patient has to die," but would open as many of the abscesses as he could, and hope for recovery.

SURGICAL ASPECTS OF ADENOMA OF THE LIVER

VICTOR L. SCHRAGER, M.D.

CHICAGO, ILL.

FROM THE DEPARTMENT OF SURGERY, NORTHWESTERN UNIVERSITY MEDICAL SCHOOL

ADENOMA of the liver may attract attention on account of the presence of a mass in the upper abdomen. It may remain silent for a long time, or so interfere with the function of neighboring organs by pressure or displacement, especially upon biliary channels or vessels, as to cause clinical symptoms. Occasionally an adenoma is discovered in the course of an upper abdominal exploration or it may be found at postmortem. The ability of the liver to compensate functional disturbances explains the absence of symptoms for long periods.

Adenoma of the liver occurs at all ages. The finding of an adenoma in young infants or nurslings suggests the congenital origin of these tumors, and such terms as "dysembryomata" and "malignant embryonal adenoma" of nurslings seem, therefore, quite appropriate. The congenital origin of adenoma of the liver is supported by various reports from the literature. Pepere[20] described malignant embryonal adenoma in nurslings. Wagner[28] found several nodules of liver tissue in the falciform ligament in two infants. Rolleston[22] found, on several occasions, minute liver lobes, which he considered congenital hepatic inclusions or rests. He believes that these segments may have been separated during fetal life from the main liver and that they subsequently became embedded into the liver. Christian found multiple nodules under Glisson's capsule. Pepere reported an adenoma of the liver proper and many small adenomata scattered over the peritoneum and omentum. Milne[18] reported an adenoma three inches in diameter in a child six months old. Hippel[12] found an adenoma in the left lobe of the liver in a girl one and three-quarters years old. Wegelin[29] encountered a primary adenoma of the liver in a boy five and one-half years old, with metastases in both liver and lungs, and reported three other adenomata found in the suspensory ligament of the liver in a man 72 years old. Kauffman has also described several cases of adenoma in people over 70 years of age.

The views concerning the origin and development of adenomatous masses in and about the liver may be grouped as follows:

(A) Congenital origin (Rolleston, Christian, Pepere, Milne, *etc.*), due to hepatic inclusion in embryonal life or pedunculation.

(B) Mechanical segmentation of liver tissue by tight lacing, belts, *etc.* Continuous pedunculation of a segment of liver may hang by a long pedicle from the liver proper as shown in the Anatomic Museum of Cambridge. Chaillous[5] found several large accessory lobes of liver attached to the lower border of the liver close to the falciform ligament. A specimen in St. George's Hospital museum shows the left lobe of the liver separated from

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the right lobe by a distance of three inches and connected by a pedicle. Several cases have been reported in which accessory lobes were entirely separated from the liver proper and were attached to the gallbladder.

(C) Nodular, compensatory hyperplasia. Destruction of liver tissue by cirrhosis, sepsis, malaria, poisons of various kinds develops hyperplastic nodes of adenomatous tissue, a reparative phenomenon.

(D) From adrenal rests (de Vecchi, Schmorl, Beer, Oberndorfer), C. V. Weller[30] describes misplacement of an entire adrenal under the capsule of the liver. Ramsey[21] describes a malignant hypernephroma of the liver in a man of 57, the tumor "originating from embryonal adrenal rests in the liver." Stoerk and Wilson and Willis expressed their doubts about real hepatic hypernephroma. Rolleston comments on this controversy as follows: ". . . but, just as in the case of renal hypernephroma, so in the case of hepatic hypernephromas doubt must be faced as to the adrenal origin." However, the reverse situation seems to have been encountered by T. S. Cullen,[6] who describes and illustrates several nodules of liver tissue embedded in the adrenal.

Pathology.—Adenoma of the liver may be small or large, single or multiple, encapsulated, yellowish-brown or yellowish-red, either soft or hard. The size of the tumor may vary from small cherry sized nodules to that of a grapefruit or larger. Lécène[15] reported an adenoma the size of two fists. Muir reported a liver cell adenoma in a girl of nine measuring 4×3×3 inches. Milne's case occurred in a child six months old and was three inches in diameter. Keen recorded a case 9×6 cm. Chalier and Martin[4] described a trabeculovesicular adenoma with secondary hemorrhages and malignant degeneration, the size of a fetal head. Rolleston believes, as stated before, that all these large adenomata are merely hepatic segments separated during embryonic life, with subsequent development.

Adenoma of the liver may be classified according to the origin or histologic pattern as follows:

Aschof:

(1) Liver cell adenoma (Rokitansky adenoma, acinous adenoma).
(2) Bile duct adenoma (tubular adenoma).

Gasparian:[10]

(1) Hepatocellular.
(2) Cholangiocellular.

Rolleston classifies adenoma into:

(1) Benign adenoma, or dysembryoma.
(2) Trabecular adenoma with malignant tendency, alluded to as hepatoma (Sabourin).

He further classifies adenomata as originating from:

(a) Liver cells (acinous adenoma).
(b) Bile ducts.
(c) Inclusion of adrenal rests.

The hepatocellular adenoma is usually single, light brown, reddish or grayish-white, soft and encapsulated. It mimics the pattern of the liver lobule. The strands of polyhedral cells, however, are not regularly arranged around a central vein like in the normal hepatic lobule. The cells are larger, often containing fat, and may secrete bile; there is present a network of capillaries and convoluted liver cells.

The acinous type may be transformed into the tubular type if bile secretion takes place and if there is a central disintegration of the tumor, or if hemorrhage takes place. These evolutionary changes may go beyond this stage and form a cystic adenoma.

The bile duct adenoma (tubular adenoma) is grayish, on account of the richness of connective tissue. It consists of woven strands of cells resembling bile ducts. The cells are columnar, and according to Gasparian[10] they occur most commonly in men of advanced age. The epithelium of these cells may become ciliated, as was the case in the tissue studied by Cagnetto.[3] These adenomata belong to the functionating types of tumors. According to Rolleston, bile duct adenoma has a tendency of indenting and displacing, but not invading, the surrounding liver substance.

Adenoma of the liver is considered by some a reparative phenomenon in cirrhosis of the liver, as well as other destructive processes, such as malaria, venous engorgement, and sepsis (Yamasaki). In experimental blastomycosis in guinea-pigs, liver destruction is followed by multiple, encapsulated areas of hyperplasia. Supranumerary lobes are often found in cirrhosis of the liver. Regenerated liver substance forms small, pale nodules difficult to differentiate from adenoma. The lack of encapsulation of these nodules classifies them as distinctly cirrhotic in origin (Heller[13]). Caminiti[2] reported 22 cases of solitary adenoma, four of which showed cirrhosis. Guitérez and Mousérat[11] found rich, new growing bile ducts in a cirrhotic node. Likewise, Marchand and Ciechanowsky and others found in these hyperplastic nodes, inter- as well as intracellular biliary capillaries. Thöle[26] and Rosenstrisch[23] cite many cases of cirrhosis without the presence of adenoma, and several cases of adenoma without cirrhosis. The articles of these two writers dwell at length upon this controversy. Kretz[14] states that adenoma and adenocarcinoma are exceptionally found in noncirrhotic livers.

Adenoma is subject to many structural changes. A common occurrence is cystic degeneration, usually due to hemorrhage or bile secretion. Leppman[16] collected nine cases of adenoma with cystic changes. Shattuck's[25] case of cystic adenoma contained four quarts of yellow fluid. The histopathology differentiated this cyst from what may have been termed "simple cyst of the liver." Some of these cystic adenomata may undergo papillomatous changes. Adenoma may undergo fatty changes, be the seat of hemorrhage, soften, and occasionally cause portal thrombosis. Transitional forms from hyperplasia to adenoma and from adenoma to carcinoma have been described by Grawitz. Adenomata are usually pure tumors of one type or another, yet in the case of Hippel,[12] a girl of 21, there was a mixed tumor

showing adenomatous tissue, cartilage, and keratosing pavement epithelium and pigment.

The malignant potentiality is emphasized by most writers, especially in those people with a "cancerous constitution." Heller[13] states that it is often quite difficult to differentiate adenoma from carcinoma, both grossly and microscopically. Perls[19] and Greenfeld[9] were among the first to observe metastases from adenoma of the liver, although they do not consider this phenomenon a final proof of a cancerous nature of adenoma. In order to determine the malignant character of adenoma, serial sections must be made through the entire tumor. Gasparian[10] discusses the case of an adenoma in which portions of the tumor looked like hypernephroma, while the others looked like adenoma.

The diagnosis and differential diagnosis of adenoma of the liver have a wider range than one might suspect. In the first place, if the adenomatous mass is palpable, one has to distinguish it from other tumors in the upper abdominal quadrant. Tumors of the liver proper, such as angioma, cavernoma, lymphangioma, myoma, teratoma, embryoma, as well as other rare benign tumors of the liver, are difficult to diagnose before operation, and as such, their identification is merely conjectural. Ascoli,[1] analyzing the histories of 16 patients admitted to the Clinica Chirurgica of Rome with the diagnosis of primary tumor of the liver, found that two were gummata, four sarcomata, six epitheliomata, one lymphangio-endothelioma, and one cavernoma. If the cystic adenoma becomes large and is dragged downward, it may be confused with an ovarian cyst. Cystic tumors, such as ecchinococcus cysts or cyst adenoma, may be suspected by their softer consistency, larger size, and in the case of the former, the diagnosis can be established by the complement fixation test, while in the case of the latter, it can be suspected by the association with cysts in other organs, as well as a familial tendency. Hemangioma (cavernoma, nevus) may be simple or multiple, associated with vascular tumors elsewhere, but as a rule is discovered at autopsy. These tumors may grow slowly and attain a large size. A vascular tumor, reported by Major, Black and Donald,[17] first noticed in a patient age 16, ended fatally 18 years later when it weighed 40 pounds. Rubin[24] reported a huge, pedunculated hemangioma gravitating into the pelvis and interfering with a pregnant uterus. The tumor was successfully removed.

Solitary tubercles may attain large size and simulate a tumor. During exploration or postmortem examination, small, typical tubercles will always be found in the vicinity of the larger tubercle. Finkelstein[8] reports a case of tuberculoma, the size of a man's fist, the removal of which required partial resection of the liver.

Gumma of the liver is often mistaken for adenoma and vice versa. According to Kauffman, gummata are not found deep in the liver substance and their seat of predilection is in the suspensory ligament or hilus. Gummata are notorious for their mimicry of many pathologic processes. Gummata are single or multiple, project beyond the surface of the liver, are

globular or irregular in shape. They are usually grayish-white on the surface and yellow on section. The Wassermann reaction is often negative, in fact much more frequently negative than in other types of visceral lues (McCrae and Craven). The spleen is often enlarged and there may be slight fever present. The therapeutic test is of value. There is frequently evidence of perihepatitis on the convexity of the liver.

An accurate diagnosis of adenoma of the liver is in most cases a mere guess. All a careful diagnostician can be expected to establish is the presence of a tumor in and about the liver. Pneumaperitoneum, cholecystography, and other types of roentgenologic examination may be of some help.

The symptomatology of adenoma of the liver offers nothing pathognomonic. Biliary and hepatic symptoms may be due to compression of the gallbladder, biliary channels, or neighboring blood vessels. The ability of the liver to compensate hepatic interference explains the clinical silence of these tumors, which are often discovered accidentally. The position and anatomic relation of these tumors explain pain in the back, shoulders, dyspeptic, intestinal and even urinary symptoms, depending upon whether the tumor compresses the gallbladder, duodenum, stomach, or the right kidney. An adenoma of the left lobe of the liver over the stomach may simulate a pancreatic cyst. The case of Fischer[7] suggested appendicitis. The patient, a young woman 24 years old, complained of dull ache in the right hypochondrium with paroxysms of pain associated with a slight rise in temperature. Operation revealed a tumor between the two lobes of the liver, adherent to the large intestine, peritoneum and gallbladder. If adenoma is associated with cirrhosis, the cirrhotic complex may be the conspicuous feature in the case. Softening of the tumor and invasion of a neighboring vein may present the picture of portal thrombosis. Adenoma of the liver must be differentiated from wandering liver and pancreatic tumors. All such tumors are apt to give rise to sudden symptoms on account of the twisting of their pedicle.

If one is able to establish, with reasonable accuracy, the presence of a tumor of the liver, the chief concern of the diagnostician is whether or not the tumor is malignant, particularly since the malignant potentialities, and even occasional metastases, of adenoma are well known. In this differentiation, sarcoma of the liver must also be considered. This tumor occurs most frequently in children, grows rapidly, is associated with scanty urine, ascites, and icterus.

Extrinsic pressure upon the pylorus may suggest pyloric obstruction. Adams obtained prompt relief of pyloric obstruction by removing an adenoma which pressed upon the pylorus. In our case the most conspicuous symptoms were urinary manifestations, because the tumor pressed upon the pelvis of the right kidney and upper ureter; these symptoms disappeared promptly after the removal of the adenoma. Newman relieved an hydronephrotic complex by removing a "wandering liver."

Case Report.—Miss M., age 24, white, clerk. During the past year the patient had been conscious of a sense of fulness in the right hypochondrium, never amounting to actual pain. There was, however, occasional pain in the region of the right scapula and the right lumbar region, either independent of, or referred from, the right hypochondrium. About six months ago frequency and difficulty in urination were noticed from time to time. The patient was otherwise in excellent health and had not lost weight. Her appetite was good. There was no nausea, vomiting, belching, or any other dyspeptic symptoms. Bowel movements were normal. There were no nervous manifestations, nor was fever present at any time. Menstrual history, essentially negative. Past illnesses—negative. Family history—negative.

Physical Examination.—Patient was a young woman, of short stature, to all appearances in excellent health. Skin showed no scars or other dermal lesions. There

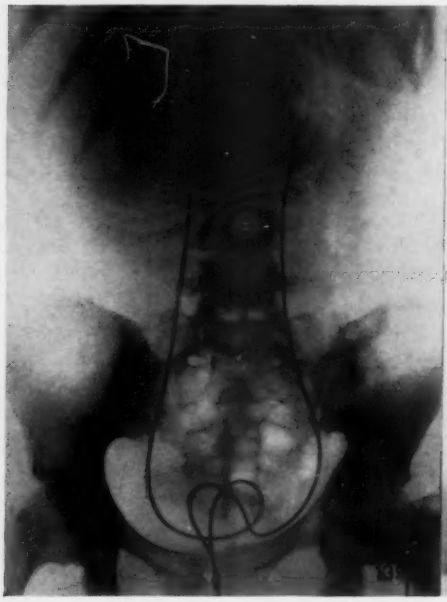


FIG. 1.—Right catheter does not go as far as the left, suggesting obstruction.

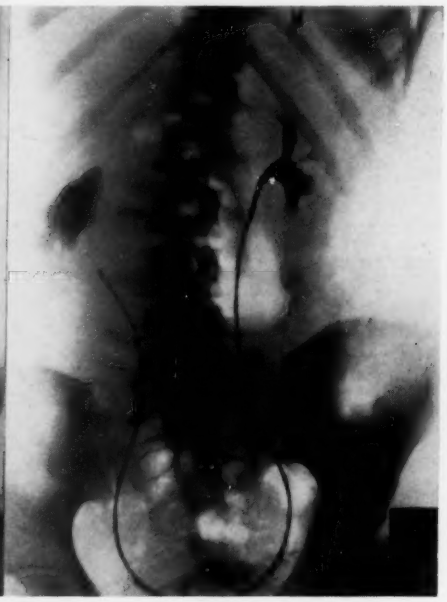


FIG. 2.—Right distended pelvis with ill-defined calices.

was no adenopathy. Reflexes, cutaneous, muscular, and tendinous, were all normal. Lungs normal. Heart normal in size, no adventitious sounds. Examination of the abdomen revealed a palpable mass below the right costal arch, in the region of the umbilical fissure. The inner, outer, and lower aspects of the tumor were appreciable; the upper border, however, was not definable. It was about the size of a small grapefruit. It was slightly painful to pressure and could be easily pushed toward the right kidney fossa. Bimanual palpation did not suggest that the mass was connected with the right kidney, as the posterior hand could be pushed into the kidney fossa without feeling the tumor in front.

Roentgenologic examination revealed an indefinite shadow below the right costal arch, but the roentgenologist would not commit himself to an exact diagnosis.

Laboratory Data.—W. B. C. 9,200. R. B. C. 4,250,000. Hb. 75 per cent. Wassermann negative. Uranalysis negative.

On account of the frequency and painful micturation and our inability to establish the anatomic location of the tumor, a cystoscopic examination was made with the idea

that it might reveal a kidney tumor which projected itself forward. It demonstrated that the ureteral catheter did not go up as far on the right side as it did on the left (Fig. 1), and suggested obstruction. Roentgenogram after skiodan injection showed the right pelvis larger than the left and that the calices were ill defined (Fig. 2). Both the urologist and the roentgenologist agreed that there was a distended pelvis, with poorly defined calices on the right side, apparently due to a moderate obstruction of the upper ureter on the same side.

Operation.—The usual kidney incision was made and the right kidney readily exposed. It was found to be normal in every respect and its pelvis likewise normal in contour, shape and size. Palpation of the upper portion of the ureter was negative. A mass could be easily felt projecting from the peritoneal cavity, contiguous with the pelvis of the kidney, and we soon appreciated that we were in error and were dealing with an intraperitoneal mass. The wound was closed and a pararectus upper abdominal incision made. Upon opening the peritoneum, a mass appeared in the region of the umbilical fissure and portal orifice of the liver. The tumor was attached to the lower edge of the liver in close relation to the suspensory ligament. It extended equally to-

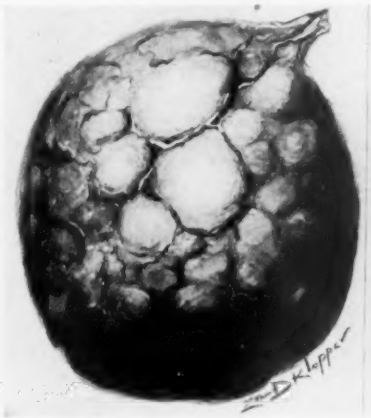


FIG. 3.—Gross appearance of tumor.

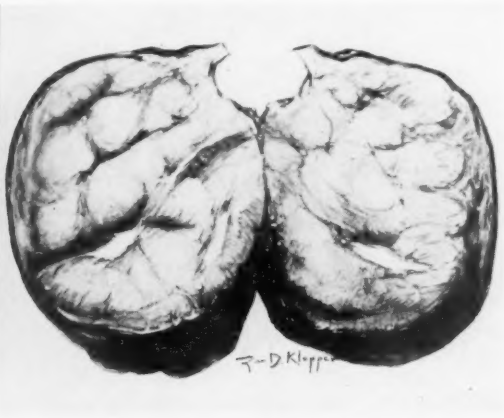


FIG. 4.—Gross appearance of tumor after bisection.

ward both lobes, and was the size of a small grapefruit. It was reddish-brown in color and resembled liver tissue. The mass was somewhat lobulated and was loosely attached to the omentum (Figs. 3, 4 and 5). A wedge shaped incision was made into the liver substance, freeing the tumor from its attachment. The defect thus made was closed with plain catgut No. 2 sutures, taking a deep bite into the liver about three-quarters of an inch from the liver defect. There was very little bleeding present and hemostasis seemed to be effected. The abdomen was closed. The patient made an uneventful recovery, and both wounds healed without suppuration.

All previous symptoms, especially the urinary symptoms, disappeared promptly after operation. Relating the experience in this case to a well known urologist: He made a sharp distinction between a dilatable and a dilated pelvis of the kidney. A pelvis may be dilatable by extrinsic pressure, even giving rise to clinical symptoms, which, however, subside when this pressure is removed, and the pelvis returns to normal. A dilated pelvis, on the other hand, is consequent to some obstruction and remains dilated even after the obstruction is removed.

Through the courtesy of Dr. Richard Jaffé we are enabled to report a second case of adenoma of the liver which was discovered at postmortem on a fatal case of ruptured ectopic pregnancy.

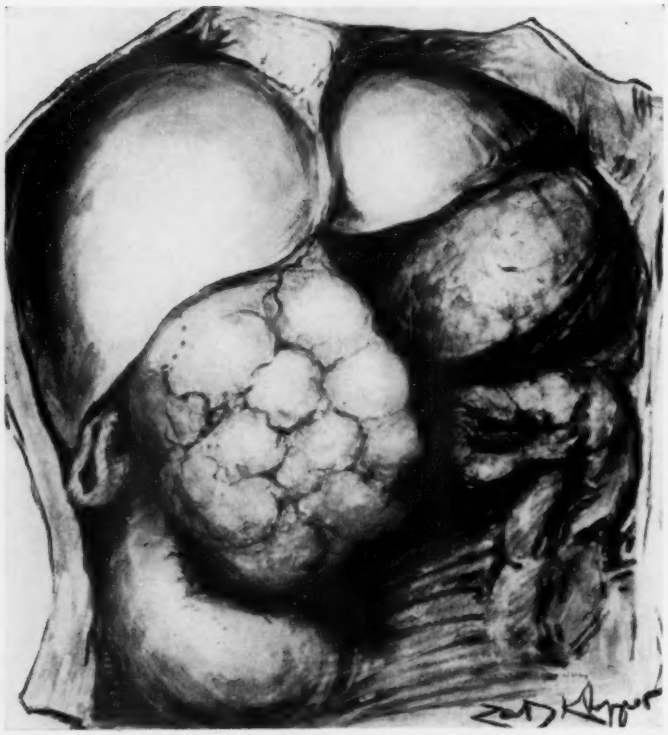
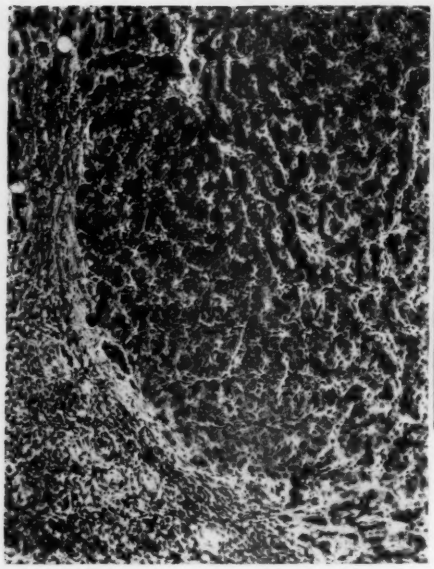
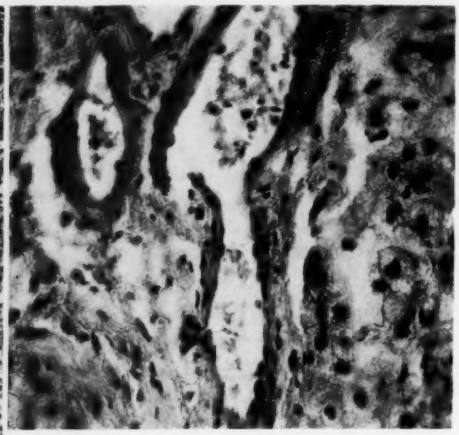


FIG. 5.—Relation of tumor to neighboring viscera.





FIGS. 6 and 7.—Histologic aspects of tumor shown in figures 3 and 4 (low and high power).

Case Report.—The patient, a colored girl, age 31, weighing 216 pounds, admitted with an acute abdomen. Diagnosis: Hemorrhage into the peritoneal cavity.

Autopsy by Dr. R. H. Jaffé revealed a ruptured ectopic pregnancy of the right tube with extensive intra-abdominal hemorrhage. The minutia of this autopsy are omitted, except the findings in the liver. The liver weighed 1,590 Gm. and was of lessened consistency. On its surface were spherical areas from 1 to 11 Mm. in diameter. In the center of the left lobe there was a firm, lobulated mass which bulged over the

FIG. 8.—Autopsy specimen showing cut surface of tumor in left lobe of the liver.

superior and especially the inferior surface of the liver. It measured 10×8×8 cm. It was light yellowish gray in color and was traversed by distended blood vessels. On sectioning, the surface showed a uniform, fine lobulation of light yellowish-brown color. The remaining cut surface was pale, brownish-gray, with indistinct markings and circumscribed firmer, light pinkish gray nodes up to 9 Mm. in diameter. In addition to these nodes, there were pinkish-brown, less sharply circumscribed areas up to 12 Mm. in diameter. The gallbladder contained thin, light yellow bile and was practically normal. Pancreas weighed 105 Gm., was lobulated, moderately firm, pale yellow.

Microscopic Examination.—(a) Tumor of the Left Lobe.—Under low power the tumor resembles early periportal cirrhosis. The parenchyma is subdivided into various sized islands by branching septa of cellular connective tissue. The islands are com-

posed of well defined cords of liver cells without arrangement about the central vein. The liver cells are of uniform size. They have an ample, finely granular cytoplasm which contains a moderate amount of medium sized and large fat droplets. The nuclei are small and vesicular. The capillaries between the liver cell cords are lined by branched endothelium. Scattered between the liver cells are small groups of tubular gland like structures lined by cuboidal epithelium. These tubulae are most numerous in the periphery of the islands, where they border the connective tissue septa. These septa vary in thickness. They contain arteries and veins with very differentiated walls, but the lack of bile ducts is striking. There is a diffuse infiltration by small, round cells of lymphocytic type, which often form nodules.

(b) Tumor of the Right Lobe.—The acinar structure is very well defined and the

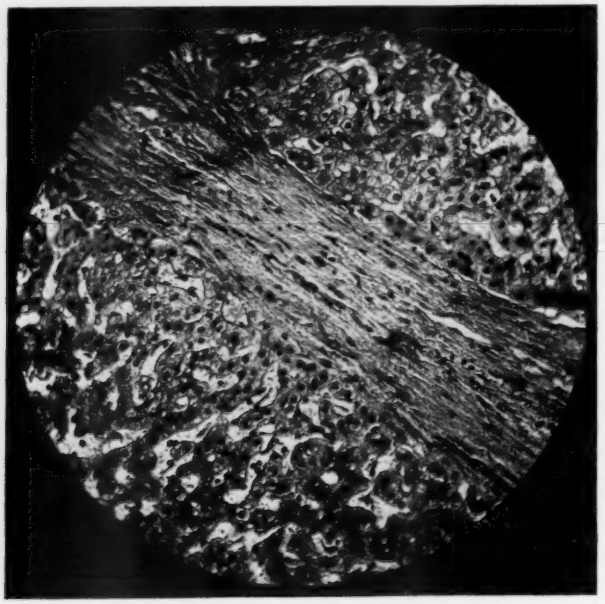


FIG. 9.—Histologic aspect of tumor shown in figure 8.

acini appear relatively large. The liver cells contain much less fat than in the tumor of the left lobe. Much fat, however, is present in the Kupffer cells. The periportal tissue is not more abundant than normal and is loosely infiltrated by leukocytes. There are areas which are composed of wide, blood filled spaces, separated by slender trabeculae of connective tissue. These blood spaces extend into the adjacent liver tissue. In some of these spaces the blood is coagulated.

The clinical case herein reported, supplemented by a second case which was discovered at postmortem, is presented with the purpose of familiarizing surgeons with both the clinical and anatomic manifestations of adenoma of the liver. While one must admit that there are no definite symptoms or laboratory methods by which adenoma of the liver can be diagnosed, a thorough knowledge of tumor masses in the right upper quadrant, coupled with a wide range of clinical possibilities occasioned by these tumors, may assist the surgeon in the differential diagnosis of upper abdominal masses in and about the liver region.

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PERFORATED PEPTIC ULCER IN MECKEL'S DIVERTICULUM

REPORT OF A CASE OCCURRING INTRAMESENTERIC

JAMES E. THOMPSON, M.D.

NEW YORK

FROM THE SURGICAL SERVICE OF THE ROOSEVELT HOSPITAL, NEW YORK, N. Y.

MECKEL[22] first described the diverticulum in 1812. During the past century frequent mention is found in the literature where this structure has been involved in various pathologic conditions.

No authentic report of a definite peptic ulcer formation within this organ was made until 1913 when Hubschmann[13] operated upon a four and one-half year old boy for an acute abdomen and found a perforated peptic ulcer in a Meckel's diverticulum. Examination of the specimen showed a typical perforated peptic ulcer with gastric mucosa lining nearly all of the diverticulum.

His findings were sufficiently important to direct surgical attention to the focus of a new disease, and since 1913 an increasing number of cases have been reported where the diverticulum has been similarly involved. The authors have been many; each one during the ensuing 20 years has helped in adding material to clarify the signs and symptoms and finally to succeed in having it recognized as a definite disease entity.

There are two main clinical manifestations resulting from this ulcer formation: the first is hemorrhage and the second perforation. Most of the available literature on this condition embraces the former, and for this reason I have chosen to analyze the perforative phase.

Anatomy.—The diverticulum, in the vast majority of cases, is found within the terminal four feet of ileum; its size varies, but will average about one inch in length with a fairly broad base. Authentic reports state that it is found in 2 per cent of the bodies examined at autopsy. It is usually situated along the antimesenteric border of the ileum, but may be found at any point around its circumference. In rare instances it is completely hidden between the leaves of mesentery. The giant cystic diverticula occasionally encountered are usually of this variety, the cystic portion communicating with the bowel lumen by a long narrow neck.

For the sake of convenience the anatomic types most commonly seen can be grouped as follows:

(1) The typical diverticulum given off from the antimesenteric side of ileum, lying free in the peritoneal cavity, and presenting a closed distal extremity (82.5 per cent).

(2) Partial obliteration with a fibrous band running from the tip of the diverticulum to the umbilicus or to some adjacent structure (10 per cent).

(3) Umbilical fistula (6 per cent).

(4) The giant diverticulum of bizarre form or shape, sometimes coming

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off from the mesenteric side of ileum and developing between the folds of the mesentery (0.5 per cent).

(5) The umbilical polyp, either attached to the remains of the omphalomesenteric duct inside the abdomen, or entirely cut off from internal connections (0.5 per cent).

(6) The simple intramesenteric variety (0.5 per cent).

The diverticulum may be lined with intestinal mucosa, duodenal mucosa, in part or entirely with gastric mucosa, with gastric mucosa and pancreatic tissue, or any combination of the intestinal, duodenal, gastric, or pancreatic elements. The type which concerns us here is the one which contains gastric mucosa, as it has been the universal experience that this is the variety in which a true peptic ulcer is likely to form.

Etiology.—Table I reveals that in all but three instances gastric mucosa was found by the pathologist. The microscopic appearance of the ulcer, its tendency to be located within that portion lined by intestinal mucosa, but closely adjoining the gastric mucosa, links it definitely from an etiologic point of view with ulcers seen in the duodenum and about the stoma of a gastroenterostomy. The evidence is so overwhelmingly in favor of the peptic genesis of these ulcers that one feels a sufficiently diligent search has not been made by the pathologist when gastric mucosa is reported absent.

Incidence.—In this group of perforated ulcers 31 out of 36 occurred in males (86 per cent). The youngest was an infant 15 weeks old and the oldest was age 53. While 36 per cent occurred in children under the age of six, there was only one case occurring after the second decade (Table I).

Past History.—Many cases give a history of previous, and often frequent, attacks of vague abdominal pain, which the mother had noticed since they were infants. In older children and adults the description is more helpful. In the case reported here the patient had frequent attacks of nausea and vomiting associated with abdominal pain years before blood was first noticed in the stool. Occasionally patients will notice a relationship between the onset of their pain and the ingestion of food, but this is a rare and undependable feature.

The most important symptom in these ulcers is a previous history of the passage of fresh blood by rectum; it is usually in the form of large dark clots freely mixed with feces and bright red blood. It should not be confused with the bloody mucus that accompanies an intussusception. They often describe an attack in which they first noticed lower abdominal discomfort rapidly progressing into "cramps" associated with nausea, then abruptly fainting. On regaining consciousness there is an urgent desire to "go to stool" with the subsequent copious passage of bright red blood. In cases of this sort they are gravely ill from the massive hemorrhage and take some time to recuperate.

The history of bleeding by rectum may have occurred years ago, or as recently as a few hours before the onset of perforative symptoms. On the other hand a perforation may occur without any previous history of bleeding

TABLE I

Number	Author	Year	Age Years	Sex	Gastric Mucosa Present	Perforation Sealed Off	Result
1.	Deetz	1907	9	M.	Yes	No	Recovery
2.	Hubschmann	1913	4½	M.	Yes	No	Died
3.	Gramen	1915	10	M.	Yes	No	Recovery
4.	Muller	1919	11	M.	Yes	No	Recovery
5.	Brasser	1924	15	M.	Yes	No	Died
6.	Guibal	1924	14	M.	Yes	Yes	Recovery
7.	Humbert	1924	11 mos.	M.	Yes	No	Died
8.	Ulrich	1925	8 mos.	M.	Yes	No	Died
9.	Etchegorry	1926	16	M.	Yes	No	Recovery
10.	Kleinschmidt (Case 1)	1927	15	M.	Yes	No	Recovery
11.	McCalla	1927	4	M.	Yes	No	Died
12.	Meiss	1928	2	M.	Yes	No	Recovery
13.	Hartglass	1928	4	F.	Yes	No	Recovery
14.	Peterman and Seeger	1928	6	M.	Yes	Yes	Recovery
15.	Schmidt	1930	18	M.	Yes	No	Recovery
16.	Fevre, Patel and Lepart (Cases 1 and 2)	1930	7	M.	Duodenal mucosa	No	Recovery
17.	Fevre, Patel and Lepart	1930	5 mos.	M.	Yes	No	Recovery
18.	Green	1930	6½ mos.	M.	Yes	No	Died
19.	Lindau and Wulff	1931	15	M.	Yes	No	Died
20.	Greenwald and Steiner (Cases 1 and 2)	1931	15 wks.	M.	Yes	No	Died
21.	Geenwald and Steiner	1931	10	M.	Yes	No	Recovery
22.	Cobb	1931	18	M.	Yes	No	Recovery
23.	Debre, Bopp and Semelaigne	1931	17 mos.	M.	Yes	Yes	Died
24.	de Vernejoiel	1932	5	M.	Yes	No	Recovery
25.	Vaughan and Singer	1932	7	M.	Yes	No	Recovery
26.	McKeen	1932	53	M.	No	Yes	Recovery
27.	Hudson and Koplik (Cases 13 and 25)	1932	6	M.	Yes	No	Died
28.	Hudson and Koplik	1932	5	F.	Yes	No	Recovery
29.*	Schaff	1932	7	M.	Yes	No	Recovery
30.	Roudil and Marty	1932	7	F.	Yes	No	Died
31.	Mondor and Lamy (Prat's Case)	1933	4½	M.	Yes	No	No mention
32.	Johnston and Renner (Case 2)	1934	18 mos.	M.	Yes	No	Recovery
33.	Weeder	1934	9 mos.	F.	Yes	Yes	Recovery
34.	Treider	1934	6	M.	No mention	No	Recovery
35.	Chesterman (Case 2)	1935	11	F.	Yes	Yes	Recovery
36.	Thompson *	1936	14	M.	Yes	No	Recovery

* Intramesenteric variety.

per rectum. One must not be confused by the story of "fever" that followed this "bloody diarrhea," as it is an almost constant feature, and is more marked in the younger subjects.

There is a moderate rise in temperature following the shock of hemorrhage, but in these cases the process is augmented by some unexplained intestinal resorptive effect. The initial rise is abrupt to about 101° F. per rectum, and varies for a few days before gradually returning to normal. In infants it may go as high as 104° F.

Present Illness.—The perforation is usually preceded by nausea and vomiting. The pain, frequently cramp like, is at first located vaguely about the umbilicus, later shifting to a point just to the right of the midline in the lower abdomen. As the perforation becomes thoroughly established, the intensity increases and the localization is more definite; while, at a still later period, the pain will diffuse over the whole abdomen as the peritonitis becomes generalized.

This description only serves to emphasize how nearly identical the picture is to that found in the abdomen in acute appendicitis. The past history plays an important part in arriving at a correct preoperative diagnosis.

The temperature at first is only slightly elevated, around 100° F., the pulse accelerated accordingly, but they mount in proportion to the spread of the peritonitis. In contrast to any previous phase of the disease, there is no blood in the stool at this time, although it is conceivable that its last appearance may have immediately preceded the onset of perforative symptoms.

The abdominal signs are acute lower abdominal tenderness, steadily increasing and localizing just to the right of midline in the hypogastrium; with attending muscle spasm which progresses to a generalized abdominal rigidity.

The onset is not as dramatic or as "lightning like" as one sees in a perforated duodenal ulcer. This may be explained in two ways. Primarily, in a duodenal ulcer the stomach contents, under pressure, are expelled through the perforation in an almost continuous stream; while in the terminal ileum the pressure is negligible and the contents are passing along in small quantities by peristaltic motion. This latter feature accounts for the "cramp like" or intermittent nature of the pain, as the intestinal contents are first extruded with each rhythmic wave of peristalsis. Secondarily, the duodenum is fixed and cannot help in sealing off its ulcerated opening against an adjacent organ or viscus, while the mobile terminal ileum, with its free appendage, can attempt to evade disaster by trying to seal its opening against bladder, omentum or neighboring intestine. This latter feature is described in greater detail under pathology.

The laboratory findings are no different from those found in acute appendicitis. There is an early elevated leukocyte count with a polynucleosis, which rises rapidly with progressive peritoneal involvement. The urine is usually negative, but may show a few pus cells or an occasional red blood cell, particularly if the diverticulum has become adherent to the bladder serosa.

Diagnosis.—The main basis upon which a diagnosis must be made is the comparatively sudden onset of an acute abdomen resembling that seen in

appendicitis, where there is a past history of the passage of a quantity of bright red blood by rectum.

If the patient is an infant, especially if a male, and the roentgenogram of the abdomen shows a gas bubble beneath the right or left leaf of the diaphragm, the diagnosis is certain. Otherwise it is a difficult diagnosis to make preoperatively, but when operating, should always be kept in mind, particularly when a diffuse peritonitis of obscure nature is encountered.

Treatment.—As soon as a diagnosis is made, an immediate operation is indicated. The best exposure is obtained through a lower right rectus incision. The diverticulum when found should be amputated at its base, and closure of the small intestine performed by any manner which has met with the greatest success by the operator when doing previous small intestine surgery.

If the perforation occurs in the intramesenteric variety of diverticulum, a resection of intestine, including the wedge of mesentery that contains the diverticulum, will be necessary. End to end or side to side anastomosis should then be performed; the latter is the safer.

Closure in the early cases should be done without drainage. In the late instances, it is a matter of individual preference and judgment as to the exact placing of the drains.

Gross Pathology.—In early cases the peritoneal cavity will be found filled with a slightly turbid, thin, and often blood tinged fluid; later this will become frankly purulent. The perforation is perhaps most often seen in the angle where the diverticulum joins the ileum, but may be encountered at any point along its surface to its very tip.

There is frequently an inflammatory reaction in the diverticulum secondary to the ulceration, giving it somewhat the appearance of an acute appendix. Undoubtedly this resemblance has accounted for the failure in the past to place them in a separate group as being primarily due to ulceration and not to inflammation. When the ulceration occurs at or near the tip, it may attempt to seal itself off against an adjacent organ such as the urinary bladder, small or large intestine. Sometimes this performance is effected, and either results in a complete resolution of the process, the production of a localized abscess, or the formation of a fistula between the ileum and the organ thus attached.

In the average case the perforation is gradually established with the expulsion first of gastric juice and mucus, then an increasing amount of small intestinal contents. The nearer to the base of the diverticulum it occurs, the greater will be the soiling and proportionately more rapid and severe the peritonitis.

Microscopic Pathology.—In order to properly interpret the microscopic pathology that can be found in these cases, it might be wise at this point to mention what one should expect to see in a normal Meckel's diverticulum.

It has been said that in about 84 per cent of the cases one will find the diverticulum completely lined with intestinal mucosa, and that in the re-

mainder (16 per cent) one finds dystopic mucosa containing acid cells histologically analogous to the fundic mucosa of the stomach. This incidence is more than likely underestimated, as the gastric mucosa when present is often scattered in small islets along the diverticular wall. Unless a conscientious and diligent search is made, it is quite conceivable that it might be overlooked. Longitudinal sections from base to tip of the diverticulum, rather than the usually circular section, are for this reason recommended as much more likely to include the gastric mucosa in elusive cases. In some instances a considerable portion of the lining is gastric in type and may even present a thickened glandular appearance to the naked eye. Here one encounters no difficulty. Occasionally islets of pancreatic tissue, or mucosa of the duodenal variety, are seen, but their presence bears no direct significance to ulcer formation at this site.

On examining the specimen which presents the perforated ulcer, it is wise to make a section passing through the ulcer and extending from base to tip of the diverticulum. Upon examining this type of section one sees the typical ulcer base lying within that zone lined by intestinal mucosa but directly adjoining the gastric area.

The ulcer is usually round, with sharp, well defined margins, showing a disrupted muscularis mucosa and a callous base. The surrounding mucous membrane may show various degrees of chronic inflammation with hyperemia and cellular infiltration. In addition there may be a superimposed acute inflammatory reaction with sufficient hyperemia and infiltration with polymorphonuclear leukocytes to greatly mask the underlying chronic pathology.

Mortality.—The mortality in the presented group of cases (which represents all that have been reported up to 1936) is 31 per cent. In the study of each individual case it is evident that the mortality increases with the length of time which elapses between perforation and operative intervention; and was lower in those cases where the perforation was "sealed off." The analysis of the different age groups bears out the findings in all surgery that the mortality increases as one gets into the lower brackets (Table II).

TABLE II

MORTALITY IN RELATION TO AGE GROUPS

Age	Mortality
Under 1 year (inclusive)	66 Per Cent
1 to 5 years (inclusive)	28
6 to 10 " "	22
11 to 18 " "	20

CASE REPORTS

B 29100.—Male, age 12, student.

Present Illness.—This boy was admitted to Roosevelt Hospital September 20, 1930. He gave a history of suffering from severe abdominal cramps 12 days prior to admission. They were first localized vaguely about the umbilicus, but gradually extended over the lower abdomen. These cramps lasted approximately six days and were terminated by the sudden appearance of bloody stools. The cramps as described were of a griping

nature and recurred about every 25 minutes, lasting usually ten to 15 minutes. The stools were soft and filled with dark clots, but also contained considerable fresh blood. On the morning of admission, while at school, he felt suddenly dizzy and abruptly fainted.

Past History.—He had been subject to attacks of nausea and vomiting most of his life. Three years ago he had a similar attack of cramps, but noticed no passage of blood. Family history negative.

Physical Examination.—General appearance somewhat anemic. Abdomen soft, no palpable masses. Liver, spleen and kidneys not palpable. No pain or tenderness on superficial or deep palpation. No visible peristalsis. Extremities: reflexes normal. Otherwise essentially negative.

Laboratory Data.—Urine. In several specimens a few red blood cells were detected. In each specimen occasional leukocytes were seen; otherwise they were negative.

Blood. September 20; Hb. 50 per cent (Talquist). R.B.C. 2,050,000. W.B.C. 6,000. Polys 66 per cent. Lymph 30 per cent. Platelets 110,000. Bleeding time two minutes. Coagulating time three minutes. Blood chemistry normal. Blood culture sterile. Blood Wassermann negative. Widal negative.

Feces. Benzidine test positive for blood.

Roentgenologic Examinations.—Abdomen and pelvis negative for any evidence of stone along the course of the ureter, or in the pelvis. Negative for any definite intra-abdominal pathology.

Course: The patient during his first two days had a quantity of bright red blood in his stools and ran a temperature which varied from 100° to 101°F. It was decided that he did not present a condition requiring surgical attention, a medical consultation was requested, and the consultant favored the diagnosis of Henoch's purpura and requested that he be transferred to the Medical Ward, where he remained until his discharge October 19.

During his stay on the Medical Ward his temperature gradually receded and on October 7 had returned to normal. His blood count gradually increased and at the time of discharge was 4,060,000. He was discharged cured with the diagnosis of Henoch's purpura October 19, 1930.

SECOND ADMISSION SURGICAL WARD, ROOSEVELT HOSPITAL.

B 31258.—May 25, 1932. Patient now age 14.

Interval History.—The patient has felt very well since his discharge. He has attended the O.P.D. from time to time for check-up examinations, and was symptom free up until two weeks ago when he began to have cramp like abdominal pains, which were severe enough to prevent him from attending school. Three days ago the cramps became so acute that he was compelled to remain at home. On day of admission his pain was so intense that the clinic doctor was requested to visit the patient at his home; and upon examination, felt that he had an acute appendicitis and suggested his immediate removal to the hospital.

Present Illness.—The patient says that the present attack of pain is much more severe than on his previous admission, and that it tends to localize definitely in the R.L.Q. Following his arrival he vomited. There have been no bloody stools or purpuric spots on this occasion.

Roentgenologic examination taken in O.P.D. a few days prior to admission reports: "G.I. Series; fluoroscopic examination and films of the stomach following a barium meal demonstrate no organic change of the stomach or duodenum. There is normal motility of the meal seen on the six hour plate."

Physical Examination.—General appearance: a well developed and well nourished young boy, lying quietly in bed. Abdomen: the palpation reveals a slight amount of rigidity of the lower right rectus muscle. There is marked tenderness over McBurney's point as well as rebound tenderness all over the abdomen. Rectal examination shows a slight amount of tenderness high on the right. Otherwise essentially negative.

Laboratory Data.—Urine negative. W.B.C. 12,200. Polys 74 per cent. Temperature 100°F.

In spite of his previous history and diagnosis of Henoch's purpura, a diagnosis of acute appendicitis was made and immediate exploration advised.

Operation.—Under gas-oxygen-ether anesthesia the abdomen was opened through a lower right rectus incision, extending from the umbilicus to the symphysis pubis. The peritoneal cavity was filled with about a pint of serosanguineous fluid. The appendix and entire ileum showed a mild degree of injection, but the appendix did not show sufficient pathology to account either for his symptoms or the peritoneal exudate. Exploration of the small bowel was commenced at about the jejuno-ileal juncture.

As the examination progressed distally a few flecks of clotted blood were found adherent to the mesentery. In wiping these off, a small nodular swelling adjoining the mesenteric border of the gut, measuring about 3½ cm. in diameter, involving the entire thickness of mesentery was found. It was situated at a point 21 inches from the ileocecal

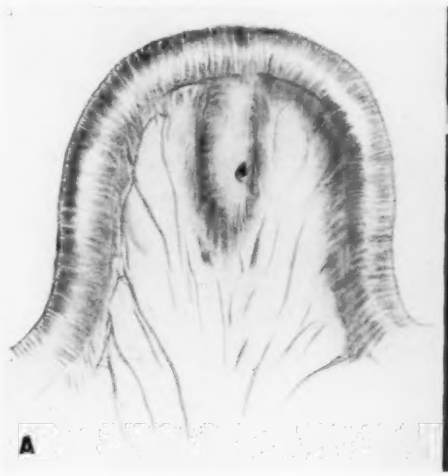

FIG. 1(A).—A diagrammatic representation of the intramesenteric diverticulum as found at operation (actually the perforation was nearer the base of the diverticulum, as can be seen in Fig. 1(B)).

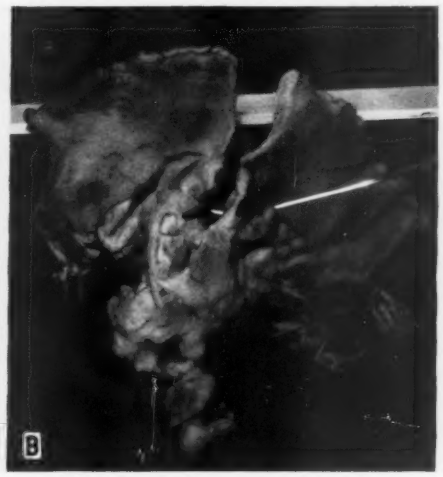

FIG. 1(B).—Showing the specimen removed at operation. The diverticulum has been opened from its tip to its base the incision being carried through the entire circumference of the already opened ileum. The probe is seen passed through the perforation from the serosal to the mucosal side. The thick adenomatous appearance of the walls of the diverticulum in its distal half is actually thick gastric mucosa.

valve. The tumor was hard in consistency, and on the side facing the pelvis presented a small perforation into which the tip of a curved clamp could be passed, and from which were expressed several drops of mucopurulent material. A probe was then passed into the opening, but at that time it was felt that it did not pass into the lumen of the gut (Fig. 1A).

Feeling that we were dealing with a small bowel malignancy, probably sarcomatous, which had perforated, it was decided to resect. This was accomplished, removing about five inches of intestine, two inches to either side of the growth, including a wedge shaped portion of mesentery that contained a few enlarged mesenteric lymph nodes. After inversion of the ends of proximal and distal loops of the bowel, a lateral entero-anastomosis was performed, using two layers of continuous tanned catgut, reenforced with several interrupted sutures at either end of the anastomosis. The leaves of mesentery were sutured to one another by means of several interrupted catgut sutures. The abdomen was closed without drainage.

Pathologic Report.—By Dr. Lawrence Sophian: Macroscopic Examination.—There is a piece of ileum 12 cm. long and 5½ cm. in circumference. In its central portion a projection into the mesenteric attachment is noted. This consists of a tubular prolongation of the intestinal wall covered with hemorrhagic, slightly roughened serosa, and measuring 2.7 cm. in length and 1.9 cm. in diameter. It has a rounded end which is covered with about 1 cm. of fat containing pale nodules which seem to be lymph nodes. The mucosal aspect of the ileum shows opposite this protrusion an opening 4 Mm. wide with somewhat elevated, smooth borders. On section through this opening there is found an expansion 1 cm. wide lined with smooth mucous membrane, and beyond this a firm mucoid wall 1 cm. thick with numerous pockets filled with mucus and many reduplicated folds of mucous membrane. There is a perforation of minute size extending through the wall at the base of the expansion and emerging under a small fold of fat on the mesenteric border (Fig. 1B). The serosal surface along this zone is covered with a deposit of fibrin. There is no gross pus.

Microscopic Examination.—Sections taken through the fundus of the diverticulum

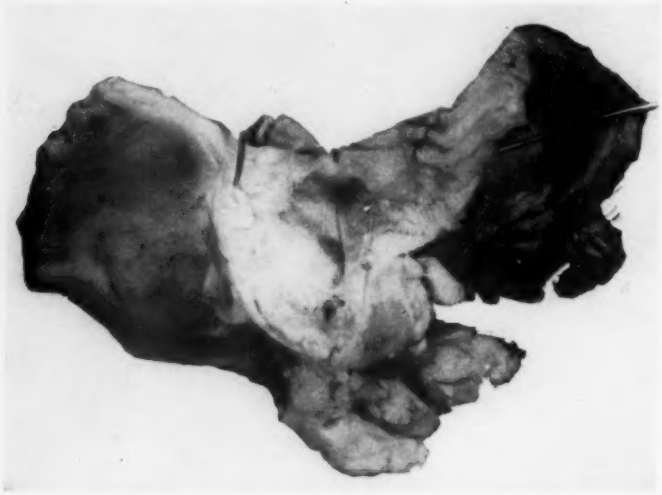

FIG. 2.—The mucosal aspect of the opened diverticulum, probe passed through the perforation. The dark spot just above the tip of the probe was a hemorrhagic spot, a probable source of fresh bleeding, accounting for the blood tinged appearance of the peritoneal fluid.

show large areas of epithelial cells which appear to resemble gastric mucosa. Both mucous producing cells and the gastric cells which produce pepsin and acid are present. The acid producing cells lie as red acid staining cells on the periphery of acini of basic staining pepsin producing cells. These gastric cells occur in large sheets and account for the bulk of the tumor mass in the diverticulum.

A section taken through the ulcerated area at the junction of the diverticulum and the gut wall shows a fibrin covered base of an ulcer underlined with an infiltration of inflammatory cells and some evidence of hemorrhage. Still deeper in this section can be seen the normal epithelium of the ileum linking the gut wall. Another section taken through one of the lymph nodes at the base of the fundus shows merely some hyperplasia of the adenoid tissue.

Diagnosis.—Congenital intramesenteric diverticulum of ileum (Meckel's) with peptic ulcer formation and perforation.

Postoperative Course.—His convalescence was uneventful until June 14, when he suddenly became nauseated and commenced vomiting. This continued through June 15 and was associated with a gradually developing distension. On June 16, after 36 hours

of vomiting and with every evidence of an acute ileus, an exploratory celiotomy was performed through the old incision. Numerous adhesions and several large bands were located and found to be causing definite mechanical obstruction. These were severed and the gut found to be viable. The anastomosis was located and gas was seen to pass through it readily. The abdomen was closed without drainage.

His convalescence from this second operation was rather stormy and on June 26 he developed a second, but less severe, intestinal obstruction which was eventually relieved by conservative means. He was finally discharged July 12, 1932, greatly improved. When last seen in September, 1935, had had no further abdominal symptoms and is now a full grown, healthy looking young man.

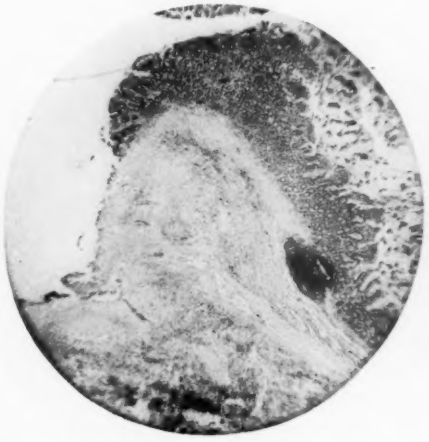

FIG. 3.—Photomicrograph of the callous ulcer base (× 30). At the top of the section passing to the right of the scarred ulcer, one sees first intestinal mucosa and then a sharp transition to the gastric type with innumerable deep seated glands.

FIG. 4.—Photomicrograph of a section taken through the gastric mucosal area of the diverticulum. The long glands with the chief and parietal type of cells are clearly demonstrated.

SUMMARY

The perforative phase of peptic ulcer formation in Meckel's diverticulum is described.

All the previously reported cases in the literature are collected and analyzed.

Great stress is laid upon the following features:

(1) The passage of a quantity of fresh blood by rectum is the most important diagnostic finding, as elicited from the past history.

(2) The tendency for the disease to manifest itself in infancy.

(3) The predilection for the male.

(4) The difficulty in making a correct preoperative diagnosis.

(5) The similarity of the abdomen to that seen in acute perforative appendicitis.

The similarity between these ulcers and those seen in the duodenum and about a gastro-enterostomy, particularly in regard to etiology, histology and pathologic physiology.

A very unusual variety is reported that has not been exactly duplicated in the past literature on the subject.

CONCLUSIONS

(1) That wider attention should be directed to a clinical entity whose probable prevalence is undetermined as yet, due to improper interpretation of rectal bleeding.

(2) That hemorrhage and perforation are the two main symptoms of the disease; and that a high mortality rate (31 per cent) attends the latter phase.

(3) That operation is indicated after the hemorrhagic phase, to obviate a future potential perforation.

(4) That immediate operation is indicated after perforation occurs.

(5) That an erect plate of the abdomen aids in making the final diagnosis.

(6) That the presence of gastric mucosa somewhere within the diverticulum is an almost constant finding.

(7) That in failing to find a typical diverticulum at operation, one should carefully search, by palpation and direct vision, the mesentery of ileum, to rule out the possibility of an existing intramesenteric variety.

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MORTALITY IN ACUTE APPENDICITIS*

FREDERIC W. BANCROFT, M.D.
NEW YORK

THERE is no doubt that there is a rising mortality in acute appendicitis. Doctor Krech has brought this out very strikingly in his report. Although I will emphasize the delayed operation in acute appendicitis, I should like to present some figures which I believe explain, somewhat, this increasing mortality. Dr. Murat Willis compiled the statistics shown in Charts 1, 2 and 3, which are based on a United States Government report of mortality per each 10,000 deaths. This has not been continued since 1925, but the rise shown, according to all reports, is still continuing in acute appendicitis.

In a study of Chart 1, it is interesting to note that the mortality dropped during the war. This may be due to the fact that many young men in the appendicitis age were overseas, or to other factors which may have entered at this particular time. During the period of preparation for the war, a great many men who had not done surgery were trained in Government hospitals for war surgery. After the completion of the war many of these men continued to do surgery. Unquestionably many of them have done excellent surgery and others have not done so well.

One can see, by a study of Chart 2, that the mortality of appendicitis in 1925 had risen above that of the puerperal state. During this same period of time there were three main advances in surgery, *viz.:* surgery of goiter, cholelithiasis and of gastric and duodenal ulcer. Chart 3 shows that there has been a proportionate rise in the mortality of these diseases. A study of the statistics of the surgical clinics of the country does not show this increased mortality. The mortality in ulcer, goiter and gallstones has decreased in the statistics presented by many surgical clinics. In appendicitis, surgical clinics present statistics that are approximately the same during the past 20 years. Finally, if we compare the United States Government mortality statistics with those occurring in surgical clinics, we must assume that the increased mortality observed in the Government reports is due to the surgery that is being performed in private sanitariums and smaller hospitals in the large cities and to the increased surgery that is being performed throughout the country in the smaller cities and outlying districts.

Table I shows published statistics during this period of time from several clinics in America. I have recently had Doctor Skoluda analyze a series of 350 consecutive cases of acute appendicitis, occurring on my own service at the Fifth Avenue Hospital, and compared it with a series which I had analyzed on Doctor Pool's service at the New York Hospital in 1920. It will

* Read before the New York Surgical Society, November 27, 1935. Submitted for publication April 18, 1936.

CHART 1

DEATH RATE IN U.S.A FROM APPENDICITIS

NOTE DECLINE IN RATE DURING WORLD WAR

DEATH RATE SHOWN IN FIGURES ON GRAPH

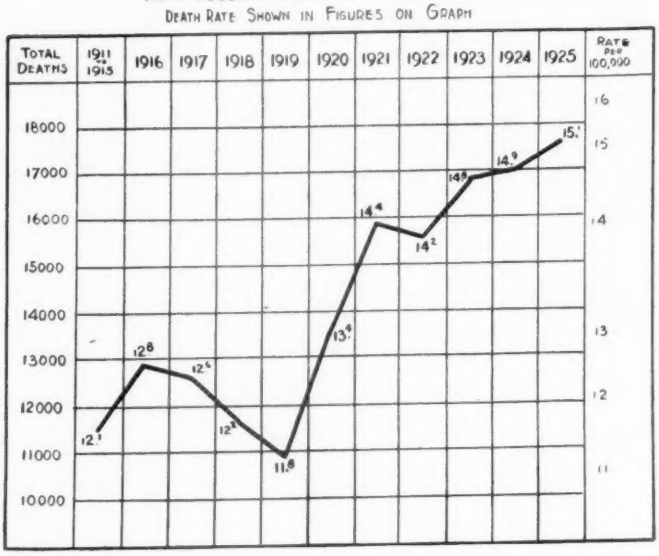
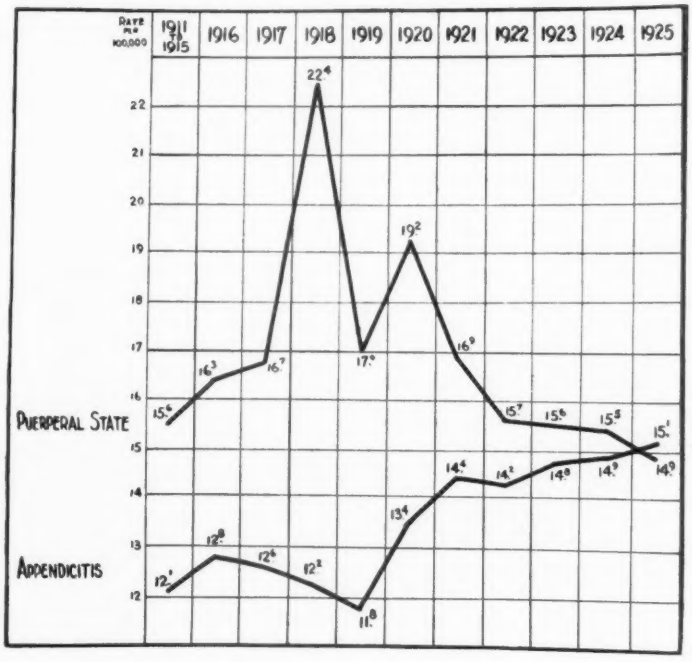


CHART 2

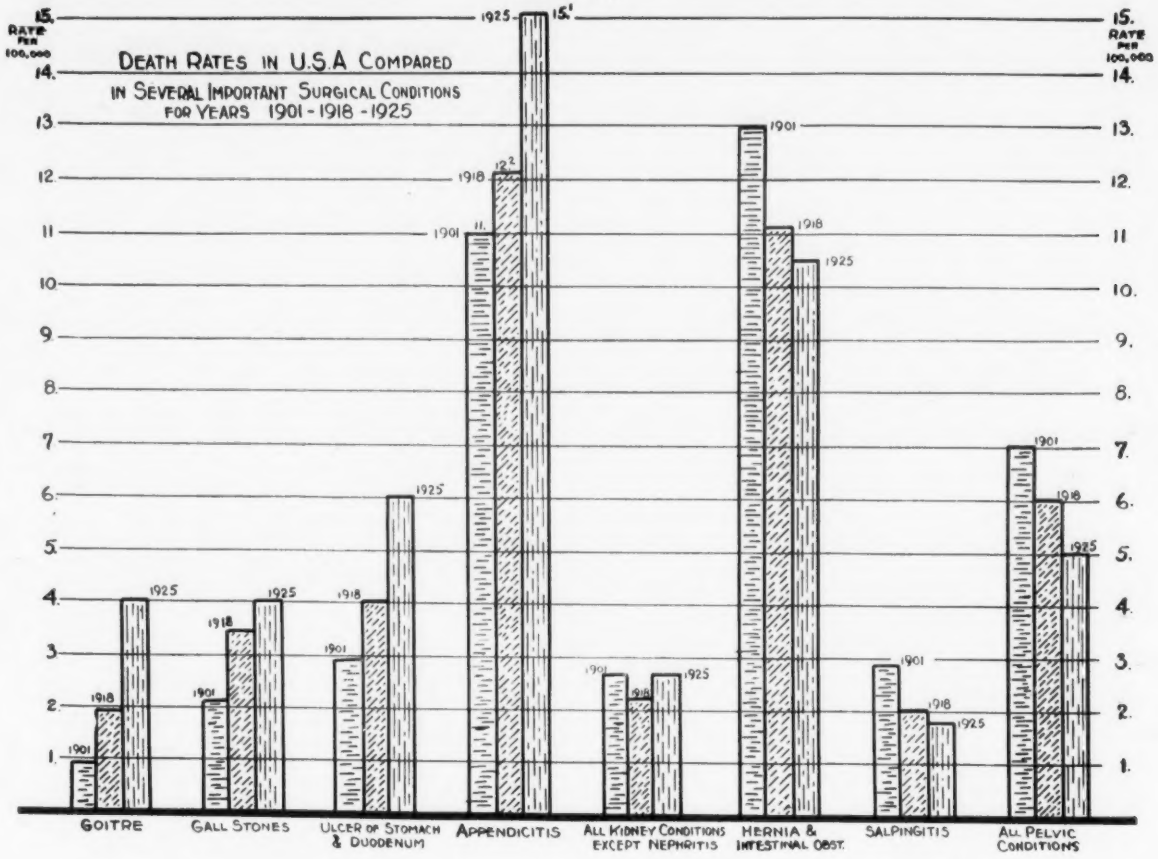
PUERPERAL STATE VS APPENDICITIS

FIGURES SHOW DEATH RATE PER 100,000 POPULATION IN U.S.A.



Annals of Surgery
January, 1927

CHART 3



be noted that the mortality rate in these two services is approximately the same, and this corresponds almost identically with the series published by Garlock, Christopher and Jennings, Finney, and McClure, in various parts of the country. It is also interesting to note that in my previous series and the present one, as is shown on Table II, the mortality is higher in the first decade of life, then decreases until the fourth decade and rises with each decade thereafter.

TABLE I

MORTALITY RATE IN VARIOUS HOSPITALS

Author	Hospital	Cases	Deaths	Per Cent
Bancroft and Skoluda	Fifth Avenue Hospital	350	15	4.3
Garlock	New York Hospital	304	17	5.5
Christopher and Jennings	Evanston, Ill.	1,138	47	4.13
Finney	Union Memorial	1,804	91	5.0
Bancroft	New York Hospital	584	25	4.2
McClure	Ford Hospital	940	29	3.0

TABLE II

MORTALITY BY DECADES

	New York Hospital			Fifth Avenue Hospital		
Age	No. of Cases	Deaths	Mortality Per Cent	No. of Cases	Deaths	Mortality Per Cent
0–10	65	7	10.9	78	4	5.1
11–20	201	5	2.4	117	2	1.7
21–30	182	2	1.1	80	2	2.5
31–40	83	7	8.5	38	0	0
41–50	43	1	2.3	16	2	12.5
51–60	6	2	33.3	14	2	14.3
61–70	4	1	25.0	6	2	33.3
71–80				1	1	100.0

A study of the mortality of the early cases where the disease is confined to the appendix or its immediate vicinity, as is shown in Table III under those cases classified Without Adjacent Peritoneal Reaction and with Free Fluid, shows a very negligible mortality. This means that if a case is referred to a surgeon in the first 24 hours the mortality is practically nil: On the other hand, if the case is delayed until abscess or diffuse peritonitis occurs, then the mortality increases to a surprising degree. In our own series of diffuse peritonitis cases at the Fifth Avenue Hospital it will be noted (Table III), that we have had eight such cases with eight deaths. I do not believe this is an accurate account of the number of spreading or diffuse peritonitis cases that were seen on our service. It is almost impossible, through a small McBurney incision, to be able to determine the general pathology. Also various men account for pathology in various ways: What one man would call Free Fluid another one might call Peritonitis.

TABLE III

MORTALITY ACCORDING TO PERITONEAL REACTION

	Fifth Avenue Hospital			Bancroft			Garlock		
	No. of Cases	Deaths	Per Cent	No. of Cases	Deaths	Per Cent	No. of Cases	Deaths	Per Cent
Without adjacent peritoneal reac.	129	0	0	246	2	0.8	245	2	0.7
With free fluid ..	148	5	3.3	127	5	3.9			
Acute diffuse peritonitis.....	8	8	100.	73	13	17.8	23	10	43.
With abscess....	46	2	4.3	133	5	4.3	36	5	13.

An analysis of Table IV reveals that the complications, with the exception of hematomata, are strikingly decreased in the undrained as compared with the drained cases. If we assume in general that the undrained cases are the early ones, this decrease in morbidity is also an important factor in advocating early operation in acute appendicitis.

TABLE IV

COMPLICATIONS IN DRAINED AND UNDRAINED CASES

	Drained		Undrained	
	No.	Per Cent	No.	Per Cent
Infected wounds	12	10.5	3	2.6
Hematomata	2	1.6	9	7.8
Secondary abdominal abscess	5	4.6	1	0.8
Intestinal obstruction	1	0.8	1	0.8
Paralytic ileus	2	1.6	0	0
Fecal fistula	3	2.6	0	0

As an effort to combat the high mortality in diffuse peritonitis and appendiceal abscess the problem of delayed operation in acute appendicitis has come largely to the fore in the last few years.

At a meeting of the Medical and Postgraduate Medical Association of Great Britain, presided over by Lord Moynihan, a very heated, and at times vitriolic debate, took place. At this particular meeting a motion was made that every case of acute appendicitis should be operated upon immediately after admission to the hospital, no matter how long after the onset of the disease it might be, and, to show the evenness of opinion on this subject, the final vote was in favor of the motion by 54 to 49.

The Ochsner method of treating peritonitis, which in England is called the Ochsner-Sherren method, has, within the last five years, gained many supporters, and the statistics given by these men are well worth considering. Love, who is its chief proponent in England, has stated that the mortality from delayed operation, after employing this form of treatment, reduces the mortality from some place between 15 and 65 per cent to an approximate 6 per cent. He states that 65 per cent of those recovering convalesced without an immediate operation, and they were sent for, to return for an appendectomy, one to three months after leaving the hospital. Twenty-five per

cent formed a localized abscess which was drained after the abscess was well localized, and 10 per cent required an emergency operation during the course of the disease. Gerry reports a mortality in the delayed operation in cases of appendicitis with peritonitis of 2 per cent. Coller and Potter, in analyzing appendicitis of the three- and five-day variety, reported 85 cases with eight deaths, a mortality of 9.3 per cent. The average length of time before the patient entered the hospital after the onset of the disease was 3.1 days. Of the 77 cases who survived, they report that 29, or 37.6 per cent, recovered without any further immediate operative procedure. Forty-eight cases, or 62.4 per cent, developed an abscess which required drainage. Staunton reports 113 cases with peritonitis. Of these 31 had an immediate operation performed, with 13 deaths, or a mortality of 42 per cent. Eighty-two had delayed treatment, with seven deaths, or a mortality of 8.5 per cent. Staunton emphasizes the fact that the more severe cases were given the delayed treatment, while the operative cases were those which they thought had the better prognosis.

It would seem that the Ochsner treatment, which was originally described in 1892, with certain modifications that have been acquired through the progress of medicine during the intervening years, should receive more attention than it does at present. It is my impression that this method is being used to a much larger degree in other parts of the country than it is in New York City. Indeed, it takes more courage not to operate than it does to operate.

In reviewing the various accounts of the Ochsner treatment it would seem possibly wise to review its salient factors. Love states that it demands four f's: fluids, fomentations to the abdomen, four hour chart (which means careful observation) and Fowler's position.

Alton Ochsner recommends: (1) the administration of fluids to combat dehydration; (2) absolute rest of the gastro-intestinal tract; (3) the application of heat to the abdomen; and (4) the Fowler position.

(1) Fluids are administered as a rule intravenously. Staunton recommends the continuous intravenous administration of saline and glucose, about 5,000 cc. in 24 hours. Ochsner recommends intravenous medication up to 3,000 cc. and prefers Ringer's solution or some modification of it, in order that calcium and sodium may be administered also.

(2) The intestinal tract is placed at rest by the administration of morphine sufficient to reduce the respiration to 12 or 16 per minute. Morphine is given, according to Ochsner, because it increases the tone of the bowel and prevents its excessive dilatation, with its concomitant intramural strangulation. While morphine is being administered Coller advises gum chewing, in order to prevent parotitis, and Ochsner suggests that oxygen be given to those cases deeply narcotized. Vomiting is prevented by the use of the duodenal tube inserted through the nares and if possible inserted deep enough so that it enters the duodenum and thus may remove the pancreatic

and upper duodenal secretions. No fluid is given by mouth and no attempt is made to move the bowels by either oral or anal administration.

(3) Many men advise the application of hot compresses, turpentine stupes or mustard pastes, but Ochsner recommends the use of a hot air tent, as he suggests it has been demonstrated by Mueller that by producing vasodilatation of the somatic area a vasoconstriction of the splanchnic vessels results.

(4) The Fowler position is recommended because it allows the gravitation of the infected exudate into the pelvis and decreases the percentage of subphrenic abscesses. In many cases the abscess may become localized in the pelvis and can be drained through the culdesac or the rectum.

My own experience in this type of case has been limited to three cases, largely because, until recently, I have been somewhat of a coward in adopting this procedure. I am convinced that the treatment must be carried out in its full detail to be successful. In the cases in which I have employed it I have been surprised to see how little distention there has been and how a seriously ill patient may recover.

On the other hand, I have operated upon two or three cases of pelvic peritonitis following appendicitis where the operative procedure apparently made the patient much worse and a fatality resulted within 36 to 48 hours postoperative.

CONCLUSIONS

It would seem to me that if we are to improve the rising mortality figures in appendicitis we must do so:

By public education, stressing strongly that cathartics should not be given in cases of abdominal pain, and that a doctor must be consulted immediately.

We must still stress, to the general medical profession, the importance of referring cases of appendicitis to the hospital early in the disease.

We must, if possible, so improve the standards of surgical practice that surgery should be undertaken by the best educated group.

We must, ourselves, improve our methods of treatment, in order to reduce the high mortality in those instances occurring of abscess and general peritonitis.

DISCUSSION.—DR. ALLEN O. WHIPPLE (New York) presented Tables I and II for the purpose of emphasizing the advantages of making a regular study of the appendicitis incidence and mortality in a hospital, so as to keep it before the staff regularly and periodically, and expressed his appreciation to Dr. Rudolph N. Schullinger[1] of the Surgical Staff of Presbyterian Hospital for his splendid and unremitting work in the past eight or nine years in compiling statistics and following them continuously.

The statistics cover a period of almost 20 years and include more than 3,000 proved cases of acute appendicitis, and represent all cases of appendicitis occurring, whether simple, appendicitis with local peritonitis, appendicitis with abscess, with diffuse peritonitis, or with progressive fibropurulent peritonitis (Tables I and II).

TABLE I

ACUTE APPENDICITIS AT THE PRESBYTERIAN HOSPITAL *

JANUARY 1, 1916, TO NOVEMBER 1, 1935 (19 YEARS AND 10 MONTHS)

Total number of cases: 3,058	144 died	Total death rate:	4.70%
Group I.—Simple acute appendicitis:			
1,375 cases	7 died	death rate:	0.50%
Group II.—Acute appendicitis with acute local peritonitis:			
752 cases	15 died	death rate:	1.99%
Group III.—Acute appendicitis with peritoneal abscess:			
632 cases	63 died	death rate:	9.96%
Group IV.—Acute appendicitis with acute diffuse peritonitis:			
357 cases	60 died	death rate:	16.80%
Group V.—Acute appendicitis with progressive fibrinopurulent peritonitis:			
26 cases	22 died	death rate:	84.61%

* In determining the total mortality rate for all the groups, these same cases, in which more than one lesion was present, were counted only as one case, and, if the patient died, only one death was recorded. This accounts for the fact the total of the individual groups (*i.e.*, 3,142) is greater than the total number of cases (*i.e.*, 3,058).

TABLE II

PROGRESSIVE FIVE YEAR AVERAGES FOR THE LAST FIVE PERIODS

1927–1931	1928–1932	1929–1933	1930–1934	1931–1935
Total cases of acute appendicitis:				
4.40%	4.08%	3.56%	3.52%	2.55%
Simple acute appendicitis:				
0.72%	0.73%	0.44%	0.21%	0.21%
Acute appendicitis with acute local peritonitis:				
1.34%	1.03%	0.50%	1.82%	1.14%
Acute appendicitis with peritoneal abscess:				
10.63%	12.84%	12.69%	10.89%	8.96%
Acute appendicitis with acute diffuse peritonitis:				
17.94%	17.44%	16.27%	14.77%	12.98%
Acute appendicitis with progressive fibrinopurulent peritonitis:				
100.%	100.%	85.71%	83.33%	60.%

One of the important factors in lowering mortality is the fact that the recognition of appendicitis by the clinician sending the case into the hospital is unquestionably better now than it was 20 years ago. He thought that physicians generally were prescribing catharsis less frequently for abdominal pain than formerly, and that the use of fluids before and after operation had resulted in tremendous improvement in the results during the last decade. Another factor responsible for the improved figures in his 20 year series, he said, is the fact that cases are drained less than formerly, or, at least, are drained more intelligently.

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DISCUSSION.—DR. FENWICK BEEKMAN (New York) discussed mortality from the standpoint of acute appendicitis in children, and stated that 12 years

ago he published a small series of cases from the Children's Surgical Service at Bellevue Hospital, of children up to 12 years of age. In that series, there was a death rate of 7.58 per cent, the children under five, however, giving a mortality of 25 per cent. Fortunately, however, the number of children under five who develop appendicitis is small. To compare with this series Doctor Beekman offered statistics on the mortality for the last 11 years and 10 months, which show a decrease of two per cent, that is, from 7.58 to 5.6 per cent. He felt rather proud of this improvement, until he commenced to analyze the mortality rate by individual years, and found there was no uniform improvement in mortality (Table I).

TABLE I

MORTALITY PER CENT BY YEARS

1924—7 %	1930—5.8%
1925—8.4%	1931—5.2%
1926—3.8%	1932—6.8%
1927—1.5%	1933—9 %
1928—3.4%	1934—2.2%
1929—5.6%	1935—7.1%

When a series comprises only a small number of cases, one or two deaths change the mortality percentage markedly, so that the only way, really, to quote mortality rates is to study large numbers of cases. Reports from individual hospitals from year to year do not mean much. The only way in which the question may be judged is from the study of large groups of cases. Children over five years of age are the most gratifying patients to operate upon for appendicitis, because their reaction is prompt. In younger children, however, under five, in whom the condition is not so easily recognized, a perforation often occurs before the disease is recognized. The peritoneum in young children does not tend to localize the infection, instead, a diffuse peritonitis is produced and, consequently, the mortality is very high. It is in these cases especially that pediatricians must be taught to recognize the condition early and before prescribing catharsis. The mortality in many children under five can be traced to catharsis having been given either by the parents or the physician who has been called in.

DR. HENRY W. CAVE (New York) said that at the Roosevelt Hospital the McBurney incision had been employed in practically every case of acute appendicitis, both male and female, since about 1887, when McBurney first used it at that hospital, the reason for so doing being the belief that it has lowered mortality. To substantiate this, Doctor Cave referred to a contribution in 1935 by Dr. Mont R. Reid of Cincinnati in which he stated that in a study of over 2,000 cases of acute appendicitis operated upon, "there has been a decrease of 50.3 per cent in the mortality rate since the operative procedure was changed from a rectus to a McBurney incision."

The operation for appendicitis may be easy to perform, or again, it may be most difficult; a great majority of young surgeons coming out from hospitals each year get the impression that it is a house surgeon's job; this is in itself a pernicious thing, and he thought it was undoubtedly one of the reasons for the high mortality in this disease.

The advantages of the McBurney incision over the right rectus incision were:

(1) There is less chance of spreading the infection, for it seems easier to wall off, with moist tail pads, the intestines through this incision.

(2) The base of the appendix is more easily reached and grasped, and thus the appendix is brought up more readily into the wound, without disturbing the coils of the intestine.

(3) As the appendix is delivered, the operator is working over on the side of the anterior abdominal wall and spilling over the side rather than back into the peritoneal cavity.

(4) Better drainage is effected, for one drain can be placed down to the base of the appendix, which is well outside the usual right rectus incision, and a longer drain can be inserted down deep into the pelvis. Thus both drains are close against the right parietal peritoneum and not placed between coils of the small bowel.

(5) Wound sloughing is less, for the reason that one need only sew the peritoneum around the drains in the badly infected cases. This cannot be done through the right rectus incision.

(6) A lowering of the incidence of incisional herniae.

Dr. Harold Neuhof (New York) said that he could not accept, without some reservation, the views just expressed to the effect that the McBurney incision is the only one to be used if a lower mortality is to be achieved, that is so far as is referable to the technical operative procedures. Thus last year, with Doctor Arnheim, he published a paper in which two three year periods were compared. It was found that there was a very definitely lowered mortality in acute appendicitis in the second period which was ascribed to various causes. The types of incision ranged between the McBurney, muscle-splitting and other incisions, and yet the mortality was lowered. The point made was that the incision should be placed in keeping with the pathologic process. He and Doctor Arnheim could see no particular reason to be tied down to any one incision and felt that, for example, if a lesion presented high up, to make an incision low down—McBurney incision—was as illogical as to make a muscle-splitting incision high up if a mass were present low down. From their viewpoint it seemed that the essential desideratum, so far as operative procedure is concerned, is to place the incision in a logical place, over a mass.

Another point worthy of comment, he felt, was in connection with the discussion as to the status of the general peritoneal cavity in cases of spreading infection from the appendix. If one does not look all over the peritoneal cavity one does not know what type of peritonitis exists on the left side of the abdomen. In a fair proportion of cases, it must be agreed by all, precise knowledge of the status of the peritoneal cavity may prove a definite lead as to whether one should or should not operate. Some eight or nine years ago, Dr. Neuof, with Dr. Ira Cohen, reported the experience of several years with abdominal puncture in acute peritoneal lesions. They employed the method in order to estimate the condition of the free peritoneal cavity in acute peritoneal lesions and particularly with regard to the status of the peritoneal cavity in diffuse peritonitis due to appendicitis. If this is ascertained, one may have a guide to the decision for or against operation. The question of the existence of generalized peritonitis ought to be subjected to a method that can give precise information. Doctor Neuhof could not recall in how many hundreds of cases abdominal puncture had been employed by himself and associates, but said that it is a safe and exact method of ascertaining the existence, or absence of, peritonitis, performed on the left side of the abdomen if one wishes to know whether acute diffuse peritonitis

exists. After some experience has been gained with the method, puncture is found only very rarely to fail to reveal pus if it is present.

Dr. Philip C. Potter (New York) thought that the task before the medical profession in lowering mortality in acute appendicitis is two-fold. First, there is the need of education of the public in regard to the possible serious nature of abdominal pain, and secondly, the improvement in method of treating diffuse peritonitis. The results of campaigns in the former task are encouraging. The second is still under discussion, chiefly as regards the matter of immediate or delayed operation. Certain arguments in favor of immediate operation make it the method of choice, in all but the exceptional case. Early operation with a minimum of trauma (spinal anesthesia and McBurney incision), in Doctor Potter's opinion, not only removes the focus of infection, but establishes the diagnosis beyond dispute. Diagnosis is not always certain before operation. A ruptured peptic ulcer and a perforated appendix with diffuse peritonitis may give a very similar history and almost identical physical findings. Cases have been encountered in which the inflammatory process has been limited to the appendix, or in which there has existed a slight degree of local peritonitis, with generalized rigidity of the abdominal wall. Here, a preoperative diagnosis of diffuse peritonitis might easily, but erroneously, be made. There is less drainage of the abdominal cavity which minimizes the danger of mechanical obstruction. The prevailing tendency is to give more attention to the prevention of paralytic ileus. At Bellevue, the endeavor is to produce a quiet intestine with normal or increased tone, but without increased peristalsis, through the use of early and repeated injections of posterior pituitary extract.

Dr. George P. Muller (Philadelphia) brought out the point that too much time is often lost between the first visit of a patient to his physician and the second visit when he is sent into the hospital. He felt that four hours should be the maximum length of time between the physician's visits in cases of suspected appendicitis. He protested against the expectant treatment of these patients at home, especially in children under five years. Regarding conflicting statistics about mortality rate in various parts of the country, he thought they might be due in part to a difference in the virulence of the Streptococcus. He agreed with Doctor Neuhof regarding the desirability of making the incision over the presenting mass, and thought that, in the case of the experienced surgeon, it mattered little whether the incision was a right rectus or a McBurney incision, but that the former was dangerous in the hands of less experienced men. Only with increasing experience does a man learn how to work in a hole. Doctor Muller was not certain that he would care to determine the status of the peritoneal cavity by puncture.

DRAINAGE OF THE ABDOMEN *

JOHN E. JENNINGS, M.D.
BROOKLYN, NEW YORK

IT HAS seemed to me that accepted practice in the matter of abdominal drainage is neither clear nor satisfactory, and that current surgical literature and teaching serve to obscure rather than to clarify the situation. I shall discuss very briefly, in terms of the abdomen only, some conflict in theory with an effort to expose certain illogical customs in practice, attempt to review the relation of the use of drainage materials to the theory of drainage, submit a criticism of such materials, and offer opinions on some modifications of current dogma and practice. Drainage of the abdomen seems to have remained more a matter of empiricism than of reason. A review of its history may be of interest.

Celsus,[1] so far as is known, first drained the abdomen for the removal of ascitic fluid. His tubes, made of lead and brass, were tapered to prevent their slipping into the abdomen and were provided with plugs to regulate the outflow. Galen[2] in the second century and Avicenna[3] in the eleventh applied this treatment for ascites, after which time no records are found of its employment until Chauliac[4] apparently rediscovered it in the fourteenth century. Paré[5] and Ryff,[6] in the sixteenth, Scultetus,[8] in the seventeenth, and Heister,[7] in the eighteenth century, used flanged metal tubes for the purpose of the drainage of intra-abdominal fluid. The latter is believed to have used wicks with the tubes; an early application of capillary drainage. It was, however, as a result of the ovariotomies of McDowell and his followers, and with the complications of the operation, that the problem as we know it was presented. It was found that most of the fatal cases, and some that recovered, showed a collection of serosanguineous fluid in the pelvis. It was believed that this secretion disappeared and by its absorption caused death. It was evidently desirable to remove it by some form of drainage. First, secondary drainage was attempted and accomplished through the cul-de-sac, probably first by Keith[9] in 1864, who also originated intraperitoneal drainage per rectum. The vaginal attack on collections of pelvic fluid has also been attributed to Peaslee[10] and to Sims.[11] About the same time Chassaignac's[12] introduction of the soft rubber tube furnished an apparatus which was hoped would prove effective. For a few years this measure was employed but was not satisfactory. Various attempts to secure a more adequate removal of fluid than the tube drainage afforded, were made, such as intermittent removal of fluid from the tube by suction or siphonage.

A period of multiple incision for irrigation and the insertion of drainage tubes followed. The opinion became general that drainage by the in-

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troduction of any foreign body implied local irritation, plastic exudate, and a blockage of the drainage channel. Ward[13] found that drainage through the tubes ceased after 12 hours, and when gauze was used, in 24 hours. Robb[14] found this occurring in from 12 hours to five days. Fowler[15] stated that through-and-through irrigation became impossible after 36 hours. Penrose[16] noted more variation. He found one case which, at postmortem, 76 hours after operation, was free from fluid, and quotes other instances draining from three to 11 days. Fowler's method of postural tube drainage was, in his own hands and in those of his associates, of distinct value. Yates,[17] in 1905, however, completely disposed of the idea of free drainage by stating that "Drainage of the general peritoneal cavity is physically and physiologically impossible" and that "peritoneal drainage must be local and unless there is something to be gained by rendering such an area extraperitoneal or by making such an area a safe path of least resistance leading outside the body, there is aside from hemostasis, no justification for its use."

Delbet[18] had already, in 1889, drawn the following conclusions from animal experimentation:

(1) "The function of drainage tubes is contingent upon the obstruction of outlets by intestinal coils.

(2) "Tubes may become filled with coagula.

(3) "Capillary drains avoid this and are thus superior.

(4) "Adhesions rapidly form about aseptic drains isolating them from the general cavity.

(5) "Effective and durable drainage of the peritoneal cavity is impossible.

(6) "Serous discharge comes, in the majority of cases, from the tract about the drain."

The literature, however, of drainage for ascites cites instances of unobstructed drainage for many weeks. The employment of the procedure for that condition has, however, fallen into disuse and no recent studies of its duration are available. Conditions in septic infectious exudation and in ascitic transudate are not comparable. It was agreed in general that drainage of the general peritoneal cavity was impossible and search for possible means to give effective, even though brief, evacuation of generalized septic fluid was abandoned.

The practice of placing so called drains at, or near, the site of infection or in proximity to an area in which infection was feared or anticipated, has been continued. Exactly what these foreign bodies are expected to accomplish is not always clear nor is it by any means assured that they do not often do more harm than good.

It is not admitted, however, nor does it seem likely, that in all instances of intraperitoneal procedure the abdomen can be closed, undrained, without an increase in mortality, nor that drainage in itself can be as dangerous, or as deadly a procedure, as some observers suggest. One doubts, indeed, if their conduct quite coincides with their vows. Few of them would abandon

a more or less liberal pack which has had its advocates, from the days of Mikulicz[19] to those of Coffey.[20] A walling off by gauze or rubber dam or both, of a septic area with the avowed object of initiating an exudative reaction and starting, so to speak, a backfire against the anticipated spread of infection, they would say is not drainage but a pack.

It has been said that the peritoneum does not appreciate the difference between a pack and a drain, and it would seem that the distinction has not been accurately defined. May it be attempted? A drain is a foreign body introduced into a wound or body cavity for the purpose of removing fluid already present or the presence of which may be anticipated. A pack is a foreign body introduced into a wound or body cavity for the purpose of increasing pressure or inciting inflammation.

An ideal drain would be one which produced no exudate and caused no damage by its presence, which absorbed and removed the fluid present, or about to form, immediately, and which could be removed without trauma to the surrounding structures. We have no such absolutely ideal material, but it is possible that our methods might be improved!

The methods still employed for so called drainage of the abdomen are: Glass tubes, rubber tubes, gauze wicks, cotton wicks, rubber dams, and combination cigarette drains, dressed tubes, *etc., etc.* Each of these has some variation from the ideals we have set for drainage material. Glass tubes, now almost obsolete, following the gold cannula of Paré into oblivion, are probably the least irritating to the tissues, but they have other drawbacks which are evident. All of them are admittedly irritating in some degree. Spellman,[21] in considering the selection of drainage material, discusses the changes produced in the adjacent tissues of rabbits, dogs and humans when rubber tubes and gauze drains were used. He found that rubber tubing used for drains in wounds creates a granulocytic membrane on the walls of the wound where the rubber touches it, delaying healing. The rubber tubing creates, by overstimulation of the tissue and by preventing coagulation, an excessive amount of drainage in clean wounds. He concludes that it should not be employed as a drainage material in clean wounds, but that the reaction of the tissues to rubber tubing may be an advantage in draining infected wounds. This reaction is not produced by gauze. His inference, so far as it concerns us, is that rubber placed in an infected wound, in the peritoneal cavity, retards the formation of protective adhesions because of its irritating properties. Gauze placed in the wound, however, is just sufficiently irritating to encourage the process. He does not describe the nature of the rubber tubing he used in his experiments but assures us that even rubber dam is surrounded by a thin granulocytic membrane within two days after it is placed in the wound.

Gauze, then, while the least irritating of the drains mentioned, is also unfortunately one of the less effective. Its meshes are plugged by a coagulum within a few hours and any drainage that ensues will merely burrow

along its track, so that all these methods of so called drainage appear to perform, and that rather inadequately, the office of a pack.

To reiterate Yates'[22] dictum "Peritoneal drainage must be local and unless there is something to be gained by rendering an area extraperitoneal or by making, from such an area a safe path of least resistance leading outside the body, there is, aside from hemostasis no justification for its use."

Newell and Massingill[23] think that drainage is indicated when there is a large abscess cavity with shaggy necrotic edges, when bloody oozing is not controlled, after removal of a gangrenous gallbladder and in acute pancreatitis. It is evident that they are talking of what we have defined as a pack.

Davis[24] describes his method of so called drainage after operations for appendicitis, with special reference to the most desirable time for its removal. He uses a split rubber tube with an iodoform gauze strip inside, inserted to the pelvis and a cigarette drain with an iodoform gauze center, inserted either into the abscess cavity or to the side of the pelvis. His chief concern, he says, is in the removal of the drain. In 229 cases, drains were removed after the following intervals: First day—12; second day—141; third day—54; fourth day—69; fifth day—21; sixth day—21; seventh day—5; more than seven days—2. His mortality was 11 per cent. One feels that such a procedure as this is not drainage but a form of antiseptic pack. The fluid, if any be present, is able to escape only alongside of the drainage material. The iodoform impregnated gauze is a medicated pack and its removal before it has been freed by granulations will inflict fresh trauma which may easily disseminate a previously localized process.

Two questions arise. There is no absolutely ideal brain. Is there any measurably competent method available? Is there any indication for drainage of the abdomen or may we cease making too fine a distinction and frankly confine ourselves to the proper use of a pack? I shall deal with the last question first. There are indications for the removal of fluid from the peritoneal cavity—by mechanisms directed to its removal alone. By which is meant drains that do not initiate any appreciable local reaction. These indications may be said to be:

(1) The brief drainage of an early exudative peritonitis. This period in which free fluid is present may precede the wide diffusion of infection and inflammation, and the early removal of such fluid may limit the spread of infection by the disseminated exudate. There seems every reason to believe that this exudative phase varies in duration but is regularly short in so called septic cases and that a plastic phase succeeds it when drainage is futile.

(2) A prophylactic drain when, a traumatic or postoperative, exudate is anticipated. In such cases, surely, the removal of fluid is the desideratum, with no need or desire to increase its volume by irritation or dam back its discharge.

(3) A sentinel drain when a late leak, of a suture or ligature of a hollow viscus, is feared.

The indications are few when compared with those calling for definite

and competent exteriorization—which means a pack, but when they are present clearly call for what we have defined as a drain.

Is there any such thing? It should be highly and durably capillary. It must be completely sterilizable. It must be as slightly irritant as any foreign body can be. It must be easy to remove, without trauma, at any time.

Raffia is the split leaf of several varieties of palm, indigenous in Madagascar. It reaches our market in braided coils made up of strands from 30 to 60 inches long and from one-half to one-quarter of an inch wide. These strands present on section a basement membrane on which are laid a single layer of cell chambers, empty, of course, in the dry state and communicating with one another. It is very strong, having weight for weight a greater tensile strength than steel. Its single strand has a marked capillarity and in multiple strand wicks this action is of course proportionately increased. It resists fractional sterilization without any great loss of its strength. It is smooth and easily removed in a hank or strand by strand without trauma. It is tolerated by the tissues and produces less irritation and exudate by its presence than rubber or cotton. It has a much greater capillarity, and hence is more capable of removing exudate, than silk. It does not plug up but remains capable of capillary drainage indefinitely. It is so durable that it is used, for that reason, by gardeners to tie rose plants to sticks, where it resists the weather and long outlasts cotton or hemp. It is so immediately absorptive that it is used for extemporaneous dying and weaving into colored mats in kindergartens. It is easily obtained, and is cheap; two dollars' worth should supply an operating room for a year.

Technic of Preparation.—Selected strands are chosen, cleared of straggling fibers, washed in boiling soap and water, cut into standard lengths, knotted in hanks of 20 strands and wrapped in muslin packages. These are then sterilized on three successive days and set aside for use. Before using, the needed number of strands are placed in the instrument sterilizer and reboiled. The raffia is often used alone, when it acts as nearly like a perfect drain as any mechanism we have been able to find. It may be used also in combination with more irritating material when it is desired to use a pack without incarcerating the fluid.

The raffia dressed tube is the most called for of these combinations, and allows the prompt drainage of fluid. It is apparently very effective when indicated. It has been employed in several hospitals during the past 20 years, and its use not only suggests, but clearly exemplifies, what I think surgery has been losing sight of; namely, the distinction between a drain and a pack.

CONCLUSIONS

Confusion has existed, and still exists, as to the essential difference between drainage and tamponade. This is fatal to a reasonable consideration of the indications for either, and is particularly true, as the record will show, in dealing with the surgery of the abdomen.

It is suggested that the natural history of so called septic peritonitis is

insufficiently understood, and that attempts to prove preconceived opinions, by means of experiments on dogs, have displaced open minded observation of disease in man.

Most modern attempts at so called drainage of the abdomen are classified as superstitions and inefficient packing.

It is believed that a limited field remains for abdominal drainage as defined, and a new material is offered.

A field for intelligent packing is recognized.

A plea is made for more intensive and detailed study of so called septic peritonitis in man.

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Discussion.—Dr. Wm. Barclay Parsons, Jr. (New York).—The fact that drainage and packing are frequently confused, particularly among younger physicians, is exemplified almost daily on hospital rounds. If one happens to have plenty of time he can almost always start a discussion on "Why did you do so and so?" in a particular case, or "Why did you drain that case?" or "Why haven't you taken the drains out?" If there are five men, they are very apt to give five different opinions as to the proper way of draining an appendix or gallbladder, and as to why not to drain one, or to drain the other. The distinction between packing and draining is something to be carefully considered.

Dr. Donald Gordon (New York).—What is the reaction of plain serum upon this material? A good many years ago he had used what is now called

cellophane, for abdominal drains, and thought it an excellent material, that was before he found out that it was a biologic membrane and that, if there was considerable exudate, this would permeate and coagulate on the cellophane thus preventing drainage. Might not that take place in raffia?

DR. SEWARD ERDMAN (New York).—What is the possible danger of one of the strands slipping through the tubing during the removal of the drain? It would seem as if a drain, made up of so many small and slippery strands, would be rather dangerous in the abdominal cavity.

DR. JOHN E. JENNINGS (Brooklyn, N. Y.) closing.—Emphasized the fact that the material described, raffia, has a capillarity superior to that of ordinary gauze mesh or other wicks. It is very much less irritating and does not plug up as does the wick or gauze. It may be left in as long as desired. Doctor Jennings said he had left it in wounds for three or four weeks and had then been able to withdraw it, strand by strand, without even the patient's knowledge of its being done, and without trauma. He has never used antiseptics with it. Occasionally, he has used it in association with iodoform gauze as an adjunct to packing. He again stressed the fact that drainage is not the same as packing. Histologic studies show that, with packing, one uses a foreign body which causes local reaction. If one packs, it should be done with intent, so that the fluid one is dealing with will not break through. Raffia is the result of an attempt to find a drainage material with sufficient capillarity, which is not irritating and which will remove fluid, without creating more.

The insertion of a cigarette drain, where no drainage is indicated, should be abandoned. If drainage is needed, the drain should be raffia or something more like it than a cigarette drain and, if packing is desired, no half-way measure like a cigarette drain should be used.

Raffia, in its crude state, may be obtained from any seedsman or dealer in horticultural supplies.

EXPERIMENTAL STUDIES IN CAROTID-JUGULAR ANASTOMOSIS*

WITH SPECIAL REFERENCE TO THE RÔLE OF THE CAROTID SINUS

ARTHUR H. BLAKEMORE, M.D., GEORGE H. HUMPHREYS, M.D.

AND

BARRY G. KING, PH.D.

NEW YORK

FROM THE SURGICAL PATHOLOGY LABORATORY AND THE DEPARTMENT OF PHYSIOLOGY OF THE COLLEGE OF PHYSICIANS AND SURGEONS, COLUMBIA UNIVERSITY AND THE DEPARTMENT OF SURGERY OF THE PRESBYTERIAN HOSPITAL, NEW YORK

ALTHOUGH the effects of arteriovenous communication on the circulation have been well understood for some time, anastomosis of the carotid artery and jugular vein presents, however, a special problem which we have felt worthy of study. The recent discovery of the importance of the carotid sinus as a systemic blood pressure regulator made it seem likely that fistulae in this region would differ somewhat in their effects from those elsewhere. Clarification of this point gains added importance in that end-to-end carotid-jugular anastomosis has been advocated as a therapeutic procedure.

The conflicting observations, and the divergent speculations of clinicians concerning traumatic arteriovenous fistula or "aneurism" have been reviewed by Holman[8] and need not be discussed here. Experimental fistulae were successfully made in dogs in 1907 by Carrel[1] but no attempt was made to study the postoperative circulatory adjustments until, in 1920, Reid[4] published his findings on experimental fistulae. These studies had been stimulated by a previous series of experiments[2, 3] and in them attention was centered on vascular changes. Although the results of the 12 anastomoses, performed by Reid,[4] were not altogether consistent, Dog 9, which survived with an open carotid-jugular fistula for two years, developed a definite dilatation of the proximal artery as well as cardiac dilatation and hypertrophy, similar to some human cases. These studies were then continued by Holman, who, in 1923,[8] formulated the conception of the readjustments of the circulatory system to an open arteriovenous fistula which is now generally accepted. In 1924, he wrote, or collaborated, in five papers[9, 10, 11, 12, 13] in which he reviewed previously reported cases, and thoroughly studied the physiology resulting from these fistulae.

This conception is briefly, as follows: Blood pressure is normally maintained by (1) the rate of blood flow per minute (cardiac output), (2) the total volume of blood, (3) the capacity of the circulatory system, and (4) the peripheral resistance. The main effect of arteriovenous fistulae is to alter the last of these. This alteration is large or small depending upon the size of

* A preliminary report of this work was read before the Philadelphia County Medical Society, March 27, 1935. Submitted for publication March 17, 1936.

the fistula and its nearness to the heart. Since alterations in the capacity of the vascular bed can compensate only temporarily for the decreased resistance, permanent compensation must take place through alterations (increases) in the cardiac output and blood volume. The degree of these compensatory increases depends on the amount of blood which is short circuited through the fistula, which in turn depends upon the size of the fistula. Thus divergent findings can be explained by the fact that the fistulae were of different sizes. If the diameter of the fistula is no larger than that of the proximal artery, dilatation of that artery and cardiac dilatation are not great. If, on the other hand, the fistula is larger in diameter than the proximal vessel, that vessel dilates until the resistance it offers to the flow of blood through it is no greater than that offered by the fistula. In such cases both blood volume and cardiac output must greatly increase, and cardiac dilatation and hypertrophy follow.

In 1923, coincident with Holman's work, Lewis and Drury[6] published studies of two patients with old traumatic fistulae, commenting on the analogy with aortic regurgitation. In experimental studies, published a few months later,[7] they showed that the systolic blood pressure might rise, following its initial drop on opening the fistula, to even higher than its normal figure. Hoover and Beams[14] reported some clinical cases in 1924, distinguishing between true decompensation and the cardiac signs associated with fistulae. They also describe experiments in which bilateral 7 Mm. carotid-jugular anastomoses were made in dogs. Using a mercury manometer, they report no change in pulse or blood pressure on opening and closing the fistula six months later.* Reid's three articles,[15, 16, 17] published in 1925, call attention to the essential similarities of all abnormal arteriovenous communications. None of these observations, however, alter Hoeman's fundamental concept.

It is surprising, therefore, to find Babcock,[18] in 1926, advocating the establishment of end-to-end carotid-jugular anastomosis as a treatment for aortic aneurism. The rational of this procedure depends on the assumption that the expansion of an aneurism is due to the pressure on its wall. To produce a lowering of pressure in the aneurism, Babcock feels that an arteriovenous fistula beyond it is an effective means. This treatment has, since that time, been used by him and McCarthy, with what is said to be considerable success, though no extensive series has yet been reported. Furthermore, no experimental studies of this type of fistula have been published, except those done by Winslow and Walker,[20] in which blood pressure alone was studied, and from which it is difficult to draw positive conclusions.

EXPERIMENTAL PROCEDURES.—The anastomoses were performed upon dogs under nembutal anesthesia (30 mg. per kilo) with rigid aseptic blood vessel technic. All the wounds healed by primary union, and after subsidence of the initial edema, a marked continuous thrill with systolic accentuation could easily be felt. There was no evidence of cerebral anemia following

* Since these findings are inconsistent with those of all other workers, it seems probable that these fistulae had practically closed, as is often the case.

operation. The size of the vessels and of the fistulae was measured at operation and again at the time of excision or necropsy.

The experimental studies have been divided into four groups: Group I.—Studies of changes in the heart and aorta. Group II.—Studies of changes in cardiac output. Group III.—Studies of changes in arterial blood pressure. Group IV.—Some observations on the rôle of the carotid sinus.

Group I.—Studies of Changes in the Heart and Aorta Following Carotid-Jugular Anastomosis

Method.—Changes in the size and shape of the hearts of six dogs were determined roentgenologically at intervals after the establishment of end-to-

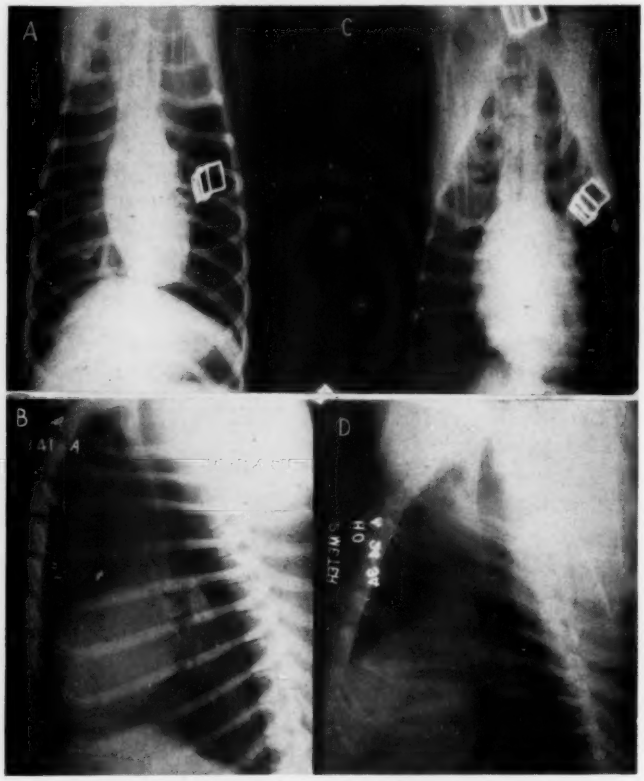

Fig. 1.—Roentgenograms of the heart of Dog 5, before and 14 months after the formation of an 8 Mm. carotid-jugular fistula. (A) Antero-posterior, before operation. (B) Lateral, before operation. (C) Antero-posterior, after 14 months of open fistula. (D) Lateral, after 14 months of open fistula.

end or side-to-side carotid-jugular fistula. The degrees of dilatation and hypertrophy were determined at autopsy. The roentgenograms were made at a tube distance of six feet, and with an exposure time just exceeding that of the cardiac cycle. At autopsy the hearts were weighed after evacuation of the contained blood. One of them was injected in situ with barium, in an attempt to demonstrate hypertrophy of the ventricular walls, in comparison with a similarly injected heart of a normal dog of comparable size and weight.

Experimental Observations.—Enlargement of the cardiac shadow regularly followed the formation of both types of carotid-jugular fistulae. These characteristic changes are shown in Figure 1. That most of the increase in size of the cardiac shadow is due to dilatation is indicated by the results of barium injection (Fig. 2). Although differences in thickness of the heart walls cannot be detected roentgenologically, this dilated heart (dog's body weight 14 kilos) weighed 19 grams more than that of the control animal (body weight 19 kilos).

Further evidence of hypertrophy of the cardiac muscle is given by the

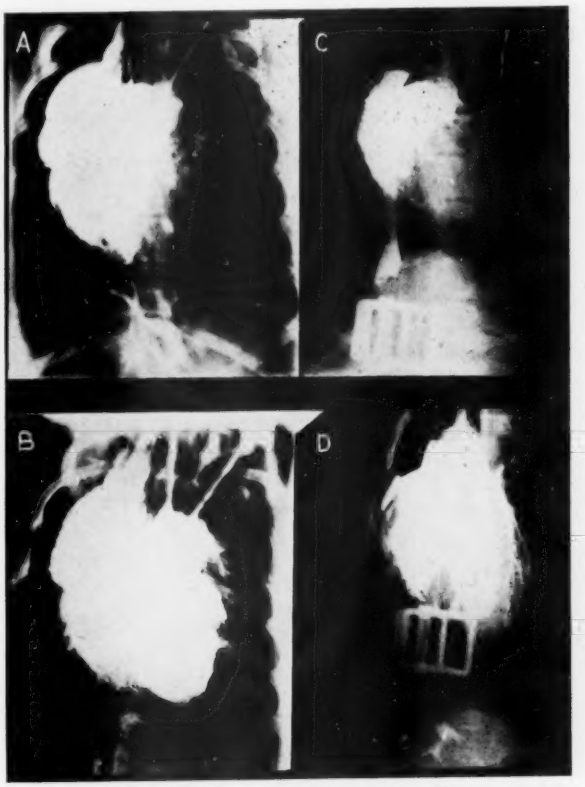

FIG. 2.—Roentgenograms of the hearts of two dogs, two meter tube distance, following injection of the heart chambers with barium. (A) Dog 4, weight 14 kilograms, three months after formation of fistula; right cardiac chambers injected. (B) Same dog; remaining chambers injected. (C) Normal dog, weight 19 kilograms; right cardiac chambers injected. (D) Same dog; remaining chambers injected.

weight at autopsy of the hearts of four other dogs (Table IV). Assuming the ratio of 7.5 grams heart weight per kilogram of body weight as normal (which seems generous on the basis of control figures of Holman and our observations), our series showed an average increase in heart weight of 48 per cent. Applying the same ratio to Holman's series of eight dogs with femoral and iliac fistulae,[12] there was an average increase in heart weight of only 16 per cent, in spite of the fistulae in his series averaging three times as large.

Since dilatation and thinning of the walls of the ascending aorta and carotid artery proximal to the fistula were noted in most of these animals at autopsy, studies of aortic size were made on two additional animals during life. The aorta was studied by attaching two silver clips on opposite sides of the aorta and a third anteriorly between them in a plane just distal to the aortic valve. Direct measurements of the distance between these clips could then be made on roentgenograms taken at a distance of six feet, with an exposure time covering the cardiac cycle. It may be seen from Figure 3 that there is no change in the distance between the clips in the control animal;

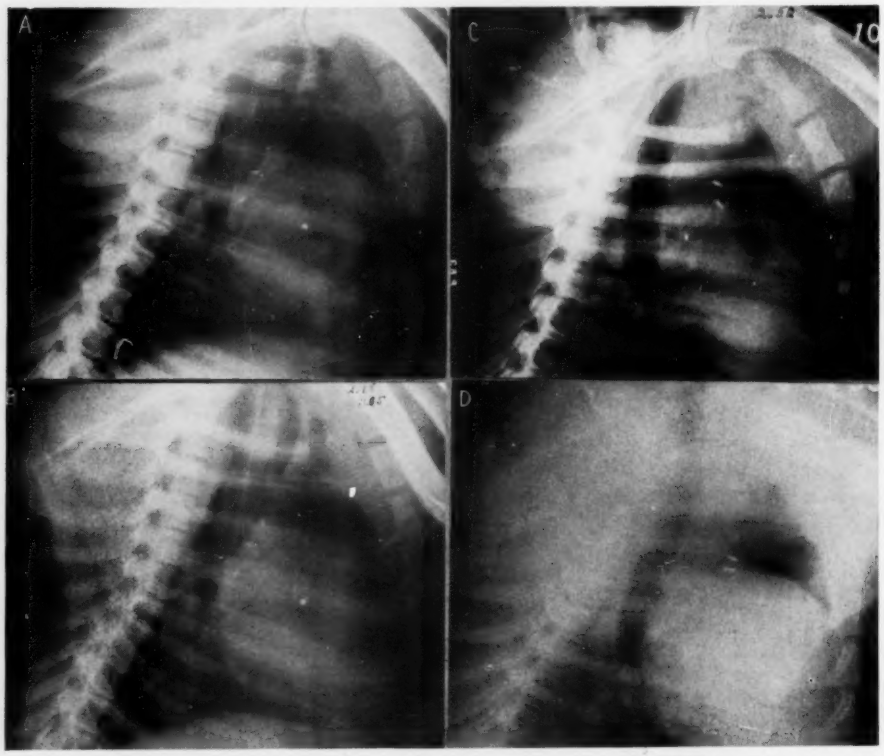

FIG. 3.—Roentgenograms of two dogs, following the attachment of silver clips to the aorta. (A) Normal dog. (B) Same dog later—the distance between clips agrees within 1 Mm. (C) Normal dog, before formation of fistula. (D) Same dog, four months after formation of an 8 Mm. end-to-end fistula; there is an increase of 4 Mm. between the clips.

in the experimental animal the change is obvious (4 Mm. by actual measurement).

COMMENT.—These heart and blood vessel changes are so conspicuous that their presence in human cases has been known for many years. As long ago as 1850 Baker[24] described them accompanying a varicose aneurism of the profunda femoris artery at its origin. He relates "the heart was greatly dilated in all its cavities, walls hypertrophied, ascending aorta dilated, communicating aperture one inch in diameter." They were observed by Reid[4] following his experimental fistulae, and he made a thorough gross and microscopic study of the degenerative changes in the vessels. It has not seemed

to us necessary to study these heart and vessel changes in our series in great detail, but merely to demonstrate their presence and degree.

Group II.—Studies of Changes in Cardiac Output Following Carotid-Jugular Anastomosis

Method.—Fifty-one determinations of cardiac output were made on six dogs before, and at varying intervals after the establishment of carotid-jugular anastomoses, and after excision of the fistulae. Under Nembutal anesthesia* the dogs were connected by means of a specially constructed conical rubber mask, with a closed respiratory system including soda-lime scrubber for removing carbon dioxide, inspiratory and expiratory flutter valves, and a Benedict spirometer. They breathed pure oxygen, and oxygen absorption per minute was determined by measurement of the respiratory tracing for periods of eight to ten minutes. A sample of mixed venous blood was obtained before disconnecting the animal, by puncture of the right ventricle, and a sample of arterial blood by puncture of the femoral artery. The oxygen content of these samples was determined by the manometric method of Van Slyke and Neill, and the cardiac output determined according to the Fick formula.

Experimental Observations.—The animals may be considered as three groups of two dogs each. Dogs 1 and 2 had end-to-end carotid-jugular anastomoses established two years before these experiments were begun. Determinations were, therefore, made before and after excision of the fistulae (Table I). The fistulae were found, upon excision, to have shrunk to a

Table I

	Dog 1				Dog 2			
	Oxygen Capacity	Arteriovenous Difference	Oxygen Consumption	Cardiac Output	Oxygen Capacity	Arteriovenous Difference	Oxygen Consumption	Cardiac Output
	Vol. %	Vol. %	Cc. per min.	Cc. per min.	Vol. %	Vol. %	Cc. per min.	Cc. per min.
End-to-end	26.2	3.0	120.0	4,000	23.9	4.2	92.8	2,210
Fistula	24.6	3.8	173.3	4,561	21.4	4.2	72.8	1,734
Open	24.0	3.1	114.9	3,705	20.0	3.2	97.8	3,056
					20.3	3.5	111.2	3,177
					20.4	3.9	101.5	2,602
After	21.8	3.6	126.1	3,503	19.4	2.6	94.8	3,646
Excision	27.5	4.4	209.1	4,752	19.9	3.2	62.3	1,947
of Fistula					20.6	2.6	66.2	2,546

diameter smaller than that of the normal carotid artery in both animals. Perhaps because of the large individual variations, no difference in cardiac output before and after excision of the fistula was evident. A small increase would be expected and might be demonstrable by a more accurate method.

* The earlier determinations were made without anesthesia other than a small amount of morphine (four mg. per kilo), but some of the dogs were found to be very difficult to train properly. Subsequently the output of trained animals was determined with and without nembutal anesthesia, and since no significant differences were noted, the remainder of the experiments were done using this anesthetic (30 mg. per kilo).

TABLE II

	Dog 3				Dog 4			
	Oxygen Capacity	Arteriovenous Difference	Oxygen Consumption	Cardiac Output	Oxygen Capacity	Arteriovenous Difference	Oxygen Consumption	Cardiac Output
	Vol. %	Vol. %	Cc. per min.	Cc. per min.	Vol. %	Vol. %	Cc. per min.	Cc. per min.
Normal	21.7	3.5	112.5	3,214	17.0	3.0	115.3	3,845
control	15.9	2.9	110.0	3,798	14.5	2.4	101.4	4,225
	16.0	2.7	100.3	3,716	16.3	3.0	92.2	3,073
After	15.1	1.5	108.8	7,256	17.4	1.1	103.6	9,418
end-to-end	15.0	2.6	80.0	3,084 *	17.5	1.8	88.7	4,928 †
anastomosis	15.6	1.0	97.3	9,730				
	16.4	1.1	89.9	8,172				

* Fistula had closed spontaneously.

† Fistula had almost closed.

Control determinations were made on Dogs 3 and 4, and large end-to-end fistulae were then established. Further determinations were made at varying intervals thereafter (Table II). One week after an 8 Mm. fistula had been made, the cardiac output of Dog 3 had increased 125 per cent. Yet five months later, his fistula had closed spontaneously, and his output was the same as in the control period. A 15 Mm. anastomosis was then established, and three weeks later his output had increased 212 per cent. A month later, it was still more than twice its original value. Similarly, the output of Dog 4 increased 153 per cent in two months after the establishment of an 8 Mm. fistula. Both these dogs became emaciated and mangey in spite of special diet and care; but when a month later the condition of Dog 4 had obviously improved, it was found that his output had fallen to only 32 per cent above normal, and autopsy revealed that the fistula had shrunk to 3 Mm. in diameter. If the animal had been allowed to survive, the fistula would have probably closed as it did in Dog 3, or a condition would have been attained similar to that in Dogs 1 and 2, where no increase in cardiac output was demonstrable by the prevailing methods.

TABLE III

	Dog 5				Dog 6			
	Oxygen Capacity	Arteriovenous Difference	Oxygen Consumption	Cardiac Output	Oxygen Capacity	Arteriovenous Difference	Oxygen Consumption	Cardiac Output
	Vol. %	Vol. %	Cc. per min.	Cc. per min.	Vol. %	Vol. %	Cc. per min.	Cc. per min.
Normal	15.9	4.6	118.9	2,582	23.0	3.2	85.3	2,666
control	17.7	3.7	92.9	2,511	22.0	4.1	93.1	2,270
	18.0	4.2	104.4	2,485	22.2	3.6	69.3	1,925
After	17.0	1.9	126.5	6,657	19.9	2.8	96.9	3,462
side-to-side	20.4	3.3	146.5	4,441	20.6	1.7	79.3	4,667
anastomosis	20.4	2.3	133.6	5,808	21.2	2.2	126.1	5,733
	19.4	2.2	115.0	5,227	21.1	2.5	115.7	4,628
After	18.5	2.8	186.2	6,650	19.3	2.5	150.0	6,015
Change to	20.2	2.5	209.5	8,380	17.3	3.3	179.0	5,427
end-to-end	18.1	3.1	204.9	6,612	17.7	2.3	125.6	5,464
anastomosis	14.7	1.5	197.5	13,166				
	16.4	1.6	176.8	11,048				
Fistula	19.9	1.4	127.6	9,112	14.7	4.1	100.3	2,447
excised	18.4	2.6	135.8	5,224	17.0	6.0	118.5	1,975

The observations on Dogs 5 and 6 are shown in Table III. After the control determinations had been obtained, 7 Mm. side-to-side anastomoses were made, and the dogs' output followed for some months; the anastomoses were then changed to end-to-end by dividing and closing the distal vessels, and further determinations were obtained; finally, the fistulae were excised and the outputs again determined. In both cases the side-to-side anastomosis was followed by a marked increase in output. In Dog 5 the average of four determinations done during three months after operation showed an increase of 115 per cent over the control average. Similarly the average increase in Dog 6 was 91 per cent during two months.

After the change to an end-to-end anastomosis, Dog 5 showed an average increase of 185 per cent in the course of eight months, during which time he became emaciated and mangey, as was noted with Dogs 3 and 4. The condition of this dog, however, then became rapidly worse, in spite of every effort to improve his condition, and during the next two months the fall in oxygen capacity of the arterial blood indicates that an anemia existed which further increased his output to enormous figures—an increase of 421 per cent being found on one determination. Since it appeared that a vicious circle existed (the anemia making the enormous output imperative, and the strain of maintaining this output preventing improvement in his anemia) which would soon have resulted fatally, the fistula was then excised. His improvement was immediate, but the output did not immediately fall to the control figures (since anemia still existed), two weeks later having fallen to 260 per cent above the control, and a month later to 106 per cent. At this time a coronary artery was wounded in obtaining the venous blood sample and the dog died before the output had returned to normal.

The reaction of Dog 6 was not so severe. An average increase of 123 per cent over the control output was found on three determinations done eight, nine and ten months after changing the side-to-side to an end-to-end anastomosis, as compared to 91 per cent before the change. His condition remained good throughout the 15 months of experiment. Determinations made one and two months after excision of the fistula were in the same range as the normal controls.

Comment.—These results are in agreement with those of Holman in his studies of femoral and iliac fistulae, differing only in degree. These carotid-jugular fistulae resulted in increases which were well over 100 per cent in contrast to the average of 78 per cent in Holman's series of dogs with fistulae approximately three times as large. The apparently greater tendency of end-to-end fistulae to close, or to shrink to a size so small that their influence on cardiac output is not apparent, has been noted by other workers. This appears to be their only difference from side-to-side fistulae.

Group III.—Studies of Changes in Arterial Blood Pressure Following Carotid-Jugular Anastomosis

Method.—Determinations of blood pressure in the femoral artery were made in six dogs before the formation of both types of carotid-jugular fistu-

lae, and at varying intervals thereafter. In four of the animals additional determinations were obtained after excision of the fistulae.

The creation of a communication between the carotid artery and the jugular vein, with its accompanying effects of increased heart rate, high pulse

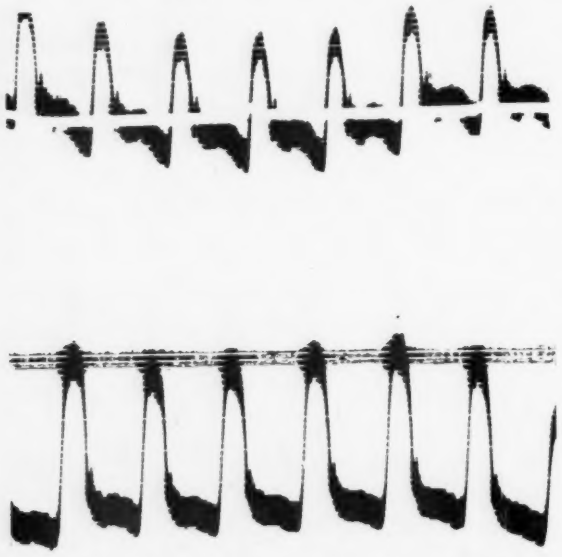

CHART 1.—Above: Photomanometric tracing from the ascending aorta of a normal dog. Below: Photomanometric tracing from the ascending aorta of a dog, nine and one-half months after the formation of a carotid-jugular fistula.

pressure, and the collapsing quality of the pulse wave, make the choice of a blood pressure registering device a most important one, particularly when the artery must be preserved for repeated determinations. The pressure wave characteristics in the presence of a carotid-jugular fistula in contrast

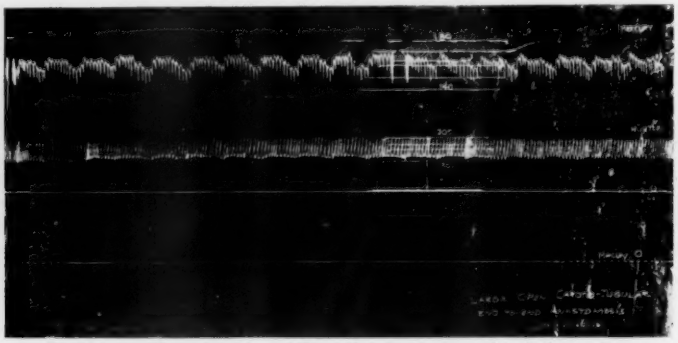

CHART 2.—Kymographic tracings from the cannulated femoral artery of Dog 4, four and one-half months after the formation of an end-to-end carotid-jugular fistula. Above: Using a mercury manometer, giving a reading of 165/150. Below: Using a Hürthle manometer, giving a reading of 200/140.

to the normal are shown in Chart 1. The high pulse wave with diminished dicrotic and postdicrotic waves noted in the lower tracing are outstanding. Failure of the mercury manometer to register true values in animals with

fistulae becomes obvious in Chart 2, where the mercury manometer, because of its inertia, fails to reveal the high pulse pressure of 60 millimeters in this animal.

After carefully evaluating the advantages and disadvantages of the current methods of blood pressure measurement, we devised, following the suggestion of Dr. Kenneth Cole, the simple instrument illustrated in Figure 4.

Technic.—After assembly and testing for air tightness, an anticoagulant fluid is aspirated into the instrument up to the zero mark on the scale. The stop-cock is then closed and the instrument is ready for use. After piercing the skin, the level of anticoagulant fluid is carefully noted before the needle is inserted into the artery. After insertion, the highest excursion of the blood-tinged fluid is noted as systolic pressure, and the lowest recession as diastolic. The needle is then withdrawn and inserted through the wall of a rubber tube filled with water and connected with a reservoir and mercury

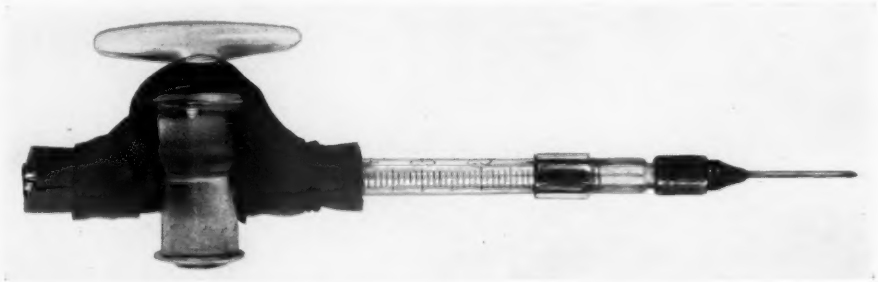

FIG. 4.—An instrument for direct blood pressure measurement. It consists of a blood pipette of 1 Mm. bore, shortened, the tip ground to take a Luer needle and the cylinder graduated in millimeters. The 18 gauge needle is 3 cm. long, with a short, rounded bevel and a sharp point. The sliding metal cuff facilitates more accurate readings.

manometer. By raising the pressure in this system, that necessary to return the fluid to the points noted as systolic and diastolic pressure can be read off directly on the manometer.

It is important that no air be allowed to enter the needle during the transfer from artery to tube, and that the level of fluid in the instrument at the moment of insertion into the tube be the same as at the moment of insertion into the artery. It is also essential that no change of temperature occur in the air contained in the instrument. Such change can be minimized by partially covering the instrument with a piece of split rubber tubing, and by making the reading immediately after withdrawal of the needle from the artery.

This method is a direct one, which neither sacrifices the vessel, nor materially obstructs the flow of blood through it. It is sensitive, and registers quick changes in blood pressure comparable to a Hürthle manometer, against which it has been adequately checked. Using the principle of compressing air in a narrow chamber, and taking the changed volume as an index of pressure are sufficiently accurate only so long as proper precautions are taken to prevent change in temperature and loss of fluid. The reflex effect of

painful stimuli on the blood pressure is another source of error to which this method is subject. Our experience in conditioning dogs for cardiac output studies have convinced us that the conditioned state mitigates to a remarkable extent the usual effects of pain. On thoroughly conditioned animals, the substantial agreement of readings with this instrument, with and without nembutal anesthesia, makes us confident of the accuracy of the results compiled in Table IV.

TABLE IV

THE BLOOD PRESSURE CHANGES IN SIX DOGS AFTER FORMATION OF CAROTID-JUGULAR FISTULAE, AND AFTER THEIR EXCISION, TOGETHER WITH CHANGES IN FISTULA SIZE AND HEART WEIGHT

Dog Number:	1	2	3	4	5	6
Blood Pressure in Femoral Artery						
Before formation of fistula:	145/75	135/70	155/105	165/120	155/95	180/105
After formation of fistula:						
1– 2 months			145/95		160/60	180/45
2– 3 months			185/105	200/120	170/70	
3– 6 months		165/60	200/140			210/70
6–12 months *					210/90	210/70
12–24 months	215/90	200/100				
24–36 months		205/100				
Change in systolic pressure:	+70	+70	+45	+35	+55	+30
Change in diastolic pressure:	+15	+30	+35	0	−5	−35
After excision of fistula	220/110 (1 mo.)	140/70 (6 mos.)		188/132 (24 hrs.)		180/120 (2 mos.)
Size of Fistula						
When made:	5 Mm.	8 Mm.	15 Mm.	8 Mm.	7 Mm.	8 Mm.
When excised:	3 Mm.	3 Mm.		3 Mm.		
Weight of Dog (kilograms)	22	15	20	14	23	20
Weight of Heart (grams)	220		185	165	247	275
Increase above Normal (per cent)	35		23	55	44	83

* Carotid sinuses denervated.

Results.—Analysis of Table IV shows that the maximum increase in systolic pressure was 70, the minimum 30, and the average 50 millimeters of mercury. There was also an increase in diastolic pressure in three of the dogs; in two the diastolic pressure returned to its preoperative level and in only one did it remain low. The pulse pressure was elevated in every case.

COMMENT.—The systolic blood pressure following arteriovenous fistulae between vessels other than the carotid and jugular is known to regain its preoperative level frequently, but it has seldom been found to exceed it by more than a few millimeters of mercury. The highest rise, reported by Holman and Kolls,[11] in Dog L28, showed a ten-millimeter rise seven months after formation of a large femoral fistula. In contrast to our findings, diastolic pressure following other fistulae remained permanently lowered.[7, 11]

This difference in the effect on blood pressure of carotid-jugular fistulae and those between other vessels suggests that other factors in addition to those enumerated by Holman[8] may come into play. We have also frequently observed conspicuous capillary pulsation in these dogs, a finding which is not recorded as occurring in those with fistulae elsewhere. Lewis and Drury[6] have called attention to the similarity of clinical signs in arteriovenous fistulae and aortic regurgitation. Furthermore, Lewis[5] has presented evidence that

the primary factor in capillary pulsation is arteriolar relaxation. The significance of these observations, as evidence of carotid sinus activity, is discussed under Group IV.

GROUP IV.—OBSERVATIONS ON CAROTID SINUS ACTIVITY IN THE PRESENCE OF CAROTID-JUGULAR ARTERIOVENOUS FISTULAE

The importance of the carotid sinuses as regulators of the systemic blood pressure, and the fact that carotid-jugular fistulae more seriously alter carotid sinus pressure than fistulae elsewhere, prompted us to make this study.

The creation of an arteriovenous fistula, as described by Holman, gives rise to two closed circulatory systems supplied by a common source, the heart; the original system (A) consisting of heart, artery, capillary bed and vein, and system (B), heart, artery, fistula and vein. Figure 5 illustrates these systems applying to carotid-jugular fistulae. The variable factors normally responsible for the maintenance of mean systolic blood pressure are: (1) Peripheral resistance; (2) cardiac output; (3) total volume of circulating blood; and (4) total capacity of the circulatory system as altered by contraction or dilatation of the vessel walls.

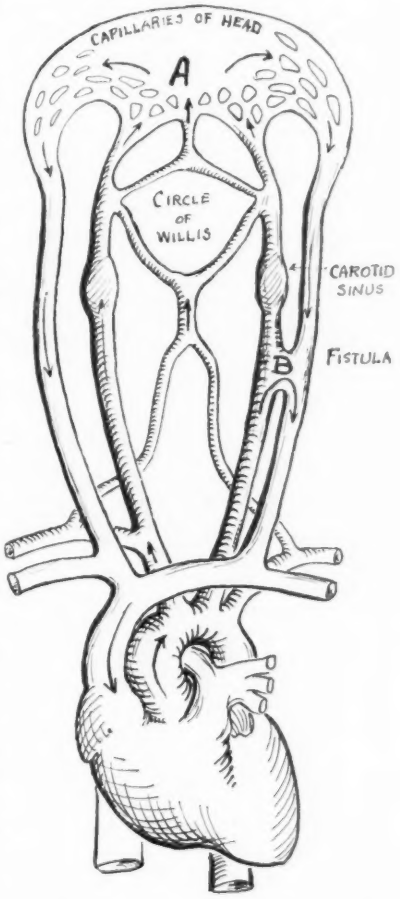

FIG. 5.—Diagrammatic schema, to show the relationship of a side-to-side carotid-jugular fistula to the systemic circulation and arterial anastomoses in the head.

An arteriovenous fistula, by creating a low resistance heart-artery-fistula-vein system (B), causes a marked lowering of peripheral resistance, factor 1. To maintain a normal flow through the heart-artery-capillary bed-vein system (A) there must be compensatory changes in the three remaining factors. To offset the large volume of blood lost to system (A) through the low resistance fistula system (B), there is an immediate increase in cardiac output, factor 2, and, later, an increase in the total volume of circulating blood, factor 3 (Holman[10, 13]). Systemic vasoconstriction would diminish the capacity of the circulatory system, factor 4. Such a change would still further lessen the amount of blood getting to the tissues through system (A) and increase the proportion of flow through the fistula, system (B).

Our present conception of the reflex mechanism controlling the caliber of blood vessels, and thus varying the total capacity of the vascular system,

represents the circular muscles of the arterioles in a state of constrictor tone. This tone is maintained by a continuous barrage of efferent impulses from the vasoconstrictor center, whose tone is in turn inhibited by continuous afferent impulses from special pressure receptors, located in the carotid sinuses and aorta.*

In agreement with Schmidt,[23] we found that occlusion of one common carotid artery in dogs lowers the carotid sinus pressure approximately 20 per cent. Occlusion of the artery was necessary in the formation of an end-to-end carotid-jugular fistula. We postulate that this type of fistula causes initially a more severe reflex vasoconstriction of the systemic arterioles than a similar sized fistula elsewhere. A severe systemic vasoconstriction in the presence of a fistula would result in an increase in blood flow through the fistula. This is borne out by the fact (since cardiac output per minute is dependent upon venous return) that the increase in cardiac output in our dogs following carotid-jugular fistulae averaged 59 per cent greater than that reported following fistulae approximately three times as large between other vessels. We further postulate that it is the proximity of the fistula to the carotid sinuses rather than proximity to the heart that largely accounts for the universal clinical impression of the seriousness of fistulae of the carotid arteries.

Since the observations to be presented were made on two animals only, they are more suggestive than conclusive. We feel they are significant, however, because (1) each response was observed repeatedly, (2) they are in essential agreement with the findings of other workers, and (3) their interpretation is in harmony with the accepted facts concerning the reflex mechanism of blood pressure control.

Experimental Observations.—These observations consist of kymographic recordings of blood pressure in two dogs during manipulative alterations of the component vessels of a carotid-jugular fistula, before and after denervation of the carotid sinuses. The records were made directly from Hürthle and mercury manometers which had been connected with a cannulated systemic artery. Intraperitoneal nembutal anesthesia was used. The mean systolic pressures recorded have been plotted on Chart 3.

* Our knowledge of the carotid sinuses has recently been materially advanced by extensive and corroborative experimental work. The remarkable experiments of Bronk and Stella,[21, 22] in which they were able to record, acoustically and photographically, the inhibitory impulses from the carotid sinuses, added much to our knowledge of the rhythmic activity of their pressure receptors. It was demonstrated that these receptors did not all have the same pressure threshold, and that individual receptors responded with a higher frequency upon an increase in pressure. Thus a great increase in sinus pressure would not only cause more receptors to respond, but also there would be a great increase in the number of impulses from individual receptors. The combined barrage of inhibitory impulses to the vasoconstrictor center would then lower systemic blood pressure. Likewise, when the carotid sinus pressure falls abnormally low, only the lower threshold receptors are stimulated and scarcely any inhibitory impulses reach the vasoconstrictor center. The result is a severe systemic vasoconstriction with a rise in systemic blood pressure.

I. *"Uncompensated" Dog.*—(a) *Effects of Clamping the Carotid Arteries.*—This dog (Chart 3) had had a side-to-side carotid-jugular anastomosis performed two days before the experiment. With the fistula closed and the circulatory path normal, clamping of one carotid artery caused an appreciable rise in systemic pressure (II), which rose still higher when both carotids were closed (III). When the side-to-side fistula was opened (V), the increases upon clamping the carotid arteries proximal to the fistula were even more conspicuous (VI and VII); when repeated after denervation of both carotid sinuses, clamping either or both carotids caused no marked change in the greatly elevated pressure which follows this procedure (XIII and XIV).

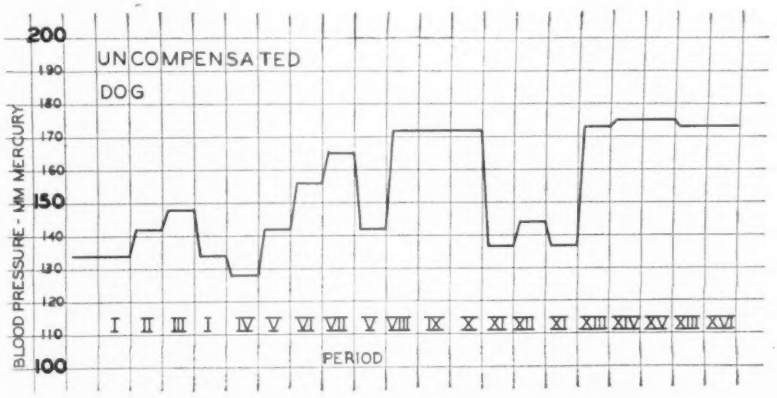

CHART 3.—Plotted blood pressure responses in an "uncompensated" dog, 48 hours after formation of an 8 Mm. carotid-jugular fistula on the left side. Continuous line represents the pressure in the right femoral artery (mercury manometer). Period I: Fistula closed, normal circulation. II: Fistula closed, right carotid artery clamped. III: Fistula closed, both carotid arteries clamped. IV: Fistula opened end-to-end (*i.e.*, with distal vessels clamped). V: Fistula opened side-to-side (*i.e.*, with no vessels clamped). VI: Fistula opened with carotid proximal to it clamped. VII: Fistula side-to-side, both carotids clamped. VIII: Fistula side-to-side, opposite carotid sinus denervated. IX: Fistula side-to-side, opposite sinus denervated and carotid clamped. X: Same as Period VIII. XI: Fistula end-to-end, opposite carotid sinus denervated. XII: Fistula end-to-end, opposite sinus denervated, carotid clamped. XIII: Fistula side-to-side, both carotid sinuses denervated. XIV: Both sinuses denervated, carotid proximal to fistula clamped. XV: Both sinuses denervated, both carotids clamped. XVI: Both sinuses denervated, fistula end-to-end.

(b) *Effects of Opening the Fistula.*—When the fistula was opened with distal carotid and jugular clamped (thus forming an end-to-end fistula), there followed a small but appreciable drop in systemic pressure (IV). When the distal vessels were unclamped, however (thus changing to a side-to-side fistula), the pressure rose to a level definitely above normal (V), the difference between these arrangements of the fistula being 14 Mm. of mercury. After denervation of both carotid sinuses, changing from a side-to-side to an end-to-end fistula caused no change in blood pressure (XIII and XVI).

(c) *Effects of Denervation of Carotid Sinuses.*—With the side-to-side fistula open, denervation of the opposite (left) carotid sinus caused a marked rise in systemic pressure (VIII). Closing and opening the carotid artery on the denervated side then failed to effect the pressure (IX and X). When

the fistula was changed to end-to-end, a fall occurred, but not to the level previous to denervation (IV and XI), and then closure of the carotid on the denervated side caused a definite additional rise in pressure (XII). Finally, after both carotid sinuses had been denervated, the elevated blood pressure was not affected appreciably by this type of fistula or the patency of the carotids (XIII and XVI).

II. *"Compensated" Dog.*—This dog (Chart 4) had had an end-to-end

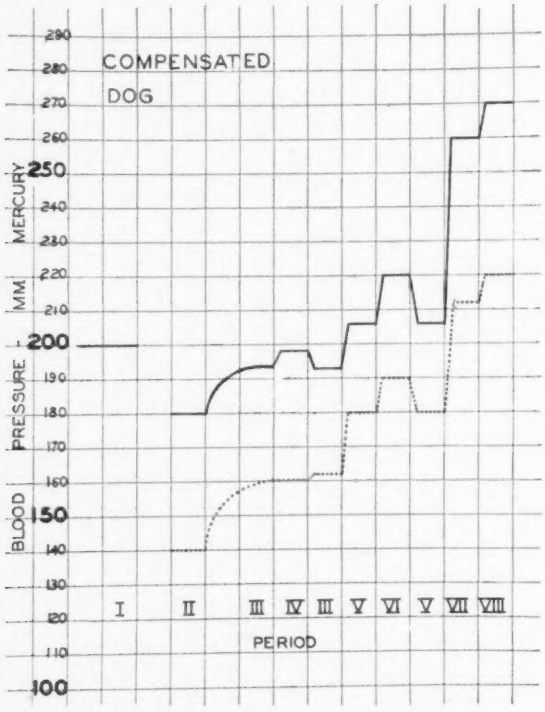

CHART 4.—Plotted blood pressure responses in a "compensated" dog (Dog 4), three months after formation of an 8 Mm. end-to-end carotid-jugular fistula, which had shrunk to 3 Mm. Continuous line represents the pressure in right axillary artery (Hürthle manometer). Dotted line represents the pressure in left carotid artery, the side of the fistula, proximal to the carotid sinus, not communicating with the fistula. Period I: Before beginning experiment. II: After 24 hours' closure of fistula (20 Mm. fall). III: After reopening the fistula (gradual rise during 15 minutes). IV: After closing fistula again (immediate small rise). V: After denervation of right carotid sinus, with fistula open. VI: Right sinus denervated, fistula closed. VII: After denervation of both carotid sinuses, with fistula open. VIII: Both sinuses denervated, fistula closed.

carotid-jugular anastomosis performed three months before the experiment, and was considered to be well compensated, with increased cardiac output and enlarged heart. It has been referred to already as Dog 4.

(a) *Effects of Opening the Fistula.*—Twenty-four hours before the experiment the fistula was clamped; during this period the mean systolic pressure fell 20 Mm. (I and II). When the fistula was then reopened (III), there followed a rise toward the previous level, in contrast to the fall which

occurred in the uncompensated animal (Chart 3, I and IV). Closure of the fistula caused an immediate further rise (IV).

(b) *Effects of Denervation of Carotid Sinuses.*—Denervation of the carotid sinus on the side of the fistula caused a considerable rise in pressure (III and V), and after both sinuses had been denervated a tremendous rise ensued (V and VII). After each of these procedures, closure of the fistula caused further increases in pressure, as it had before denervation (VI and VIII).

COMMENT.—All observers agree that opening recently formed arteriovenous fistulae, irrespective of whether they are side-to-side or end-to-end, when between vessels other than the carotid and jugular, causes regularly a marked fall in systemic blood pressure. The differences observed in carotid-jugular fistulae must then be explained, and can be attributed to effects on the carotid sinuses in the following way:

To form an end-to-end fistula, the carotid artery proximal to the sinus on that side must be closed. The pressure in that sinus, now maintained only through the circle of Willis, falls, and a vasoconstriction follows, which partially offsets the drop in systemic pressure due to the fistula, so that the resultant fall is slight (Chart 3, IV). A side-to-side fistula, on the other hand, due to the arterial communication through the circle of Willis, places the sinus, in effect, in circuit with the low resistance, low pressure fistula circuit (Fig. 5). The carotid sinus pressure, therefore, falls even lower than when the artery is closed, with a resultant reflex vasoconstriction sufficient to more than offset the effect of the fistula, and cause a definite rise above normal (Chart 3, V). When, now, the carotid proximal to the fistula is clamped, arteriovenous communication exists only through the circle of Willis, thus not only lessening the effect of the fistula itself, but also places both carotid sinuses in the low pressure fistula circuit, resulting in a further rise in systemic pressure (Chart 3, VI).

Denervation of the sinus opposite to the fistula when this is open side-to-side (Chart 3, VIII) removes practically all sinus inhibition to vasoconstriction, sending the pressure almost as high as that which follows denervation of both sinuses (Chart 3, XIII), because the low pressure in the intact sinus, due to its communication with the fistula, fails to excite inhibitory impulses. When, however, the fistula is changed to end-to-end (Chart 3, XI), and its communication with the intact sinus thus is blocked, the systemic pressure can affect the intact sinus through the circle of Willis, and stimulate inhibitory impulses which lessen vasoconstriction and result in a marked fall in pressure. No such fall follows after both sinuses have been denervated (Chart 3, XVI).

These immediate compensatory blood pressure changes are vicious in that by diminishing the fall (in end-to-end fistulae) or causing an actual rise (in side-to-side) of systemic pressure, they force a greater proportion of the circulating blood through the fistula than would pass through a fistula of the same size elsewhere. Exaggerated compensatory phenomena then ensue.

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The second animal (Chart 4) shows the result of this compensation. At the outset the formation of an end-to-end fistula, by lowering the pressure in the sinus on that side, set up a vasoconstriction which forced a large proportion of the circulating blood through the fistula. In response to the increased venous return the heart dilated, its contractile power increased and with this, its output. Progressive increase in blood volume, which is known to occur (Holman[11]) together with the increased cardiac output, raised the sinus pressure and eased off the vasoconstriction. Thus, the peripheral resistance was decreased, but the total capacity of the circulatory system was increased, necessitating a further compensatory increase in blood volume, until compensatory balance was reached between the peripheral resistance and that in the fistula circuit. Such balance was possible only with markedly elevated systolic pressure, great stimulation of the carotid sinuses, and consequent generalized vasodilatation. The hypertension and capillary pulsation which were so striking in the compensated dogs can be explained under this interpretation.

During the 24-hour period in which the fistula was closed, there was an immediate fall in cardiac output, and a beginning decrease in blood volume sufficient to result in a fall of 20 Mm. of mercury in mean systolic pressure (I and II). When the fistula was then reopened the blood volume was still sufficiently high and the hypertrophied heart was able to regain a high output with sufficient speed, so that within 15 minutes two-thirds of the fall had been regained (III). That it was not entirely regained is presumably because some loss in blood volume had occurred which could not be regained in so short a time. The immediate result of closing the fistula was to throw that portion of the circulating blood which passed through it into the general circulation, and so the pressure was increased still further (IV). In these pressure rises (in contrast to those in the uncompensated animal) vasoconstriction plays no part, since even at the start the pressure is sufficiently high to produce reflex vasodilatation. How large a factor this is, is shown by the results of sinus denervation. The sinus on the side of the fistula, being connected with the circulation only through the circle of Willis, is not subjected to the full systemic pressure. Removal of inhibitory stimuli from it, therefore, though producing a marked vasoconstrictor rise (V), cannot compare to the enormous increase of nearly 70 Mm. of mercury which follows complete denervation and consequent resumption of previously inhibited vasoconstrictor tone (VII).

SUMMARY.—After a brief review of the literature, the results of an experimental study of carotid-jugular fistulae in dogs are presented as follows:

Group I.—*Changes in the Heart and Proximal Arteries.*

Following both end-to-end and side-to-side fistulae, of variable size and duration, cardiac enlargement occurred regularly, as shown roentgenologically. Evidence is presented that this enlargement was due to both hypertrophy and dilatation. Dilatation of the carotid arteries proximal to the

fistulae was observed, and dilatation of the ascending aorta has been demonstrated.

Group II.—*Changes in Cardiac Output.*

Determinations made according to the Fick formula show increases of over 100 per cent to have occurred following the production of both types of fistulae. Changing side-to-side to end-to-end fistulae resulted in no essential change in output. Following spontaneous closure, or operative excision of the fistulae, return to a normal output is shown to have occurred.

Group III.—*Changes in Arterial Blood Pressure.*

A high pulse wave, with low dicrotic and postdicrotic waves, is shown, by photomanometric tracings, to be characteristic in animals with these fistulae, and the failure of the mercury manometer to register true blood pressure values under these circumstances is demonstrated. Blood pressure readings taken by a direct method (which is described) before and after formation of the fistulae are presented, which show a hypertension to have resulted regularly upon compensation to the fistula. The presence of capillary pulsation in dogs with compensated fistulae is noted.

Group IV.—*Some Observations on the Rôle of the Carotid Sinus.*

The marked changes in systemic blood pressure which followed manipulative alterations of the component blood vessels of carotid-jugular fistulae are contrasted in a "compensated" and an "uncompensated" animal, and are shown to have been abolished by denervation of the carotid sinuses. A hypothetical explanation of the rôle of the carotid sinuses in these changes and in the development of hypertension and capillary pulsation in the course of compensation to a carotid-jugular fistula is presented.

CONCLUSIONS

(1) The phenomena which followed anastomosis of carotid artery to jugular vein in dogs resembled those reported by previous workers following both experimental and clinical arteriovenous communications between other vessels in the following respects: there was dilatation of the arteries between the fistula and the heart, the heart was both dilated and hypertrophied, and the cardiac output was greatly increased.

(2) These phenomena differed from those previously reported in the greater degree of the changes in proportion to the size of the fistula, and in the fact that a hypertension ensued.

(3) These differences can be explained by the more direct effects on the carotid sinuses of carotid-jugular fistulae than of fistulae between other arteries and veins.

(4) In view of these effects, the production of a carotid-jugular fistula as a therapeutic procedure seems ill-advised in any case, in degenerative diseases of the aorta it is contra-indicated, and in cases with cardiac damage it is dangerous.

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THE TREATMENT OF TETANUS WITH ANTITOXIN*

AN ANALYSIS OF THE OUTCOME IN SIX-HUNDRED FORTY-TWO CASES

ROBERT W. HUNTINGTON, JR., M.D.
ST. LOUIS, MO.,
W. R. THOMPSON, PH.D.,
NEW HAVEN, CONN.,
AND
HARRY H. GORDON, M.D.,
NEW YORK CITY

FROM THE DEPARTMENTS OF PEDIATRICS AND PATHOLOGY, YALE UNIVERSITY SCHOOL OF MEDICINE, AND THE PEDIATRIC SERVICE OF THE NEW HAVEN HOSPITAL AND DISPENSARY

UNEQUIVOCAL evidence for the therapeutic efficacy of antitoxin after the onset of symptoms of tetanus has been obtained only in animal experiments,[5] and differences between the experimental disease in laboratory animals and the clinical disease in man are sufficient to invalidate any argument by analogy. Most clinicians feel that the results of serum treatment of tetanus have been very disappointing, and data from the World War experience[2,3] seem to indicate that tetanus antitoxin, invaluable as a prophylactic, is relatively useless as a therapeutic measure. Nevertheless, the continued use of antitoxin in cases of tetanus indicates that the question is not settled, and it appears that further data are desirable.

A series of 642 cases was collected from the records of a group of hospitals.[1] The authors bear the sole responsibility for the presentation and interpretation of the figures; nevertheless, in the truest sense, the work represents a joint contribution of these hospitals, and we wish to acknowledge the great courtesy which we received from their administrative and professional staffs. Particular thanks are due to the record room workers.

Seventy-two cases from preantitoxin days form a control group. The remaining cases have been grouped according to the amount of antitoxin given within 12 hours of admission to a hospital,† and according to the method of administration. Since, in experimental tetanus, serum is apparently most effective if given intrathecally,[5] special attention has been given to the cases of patients treated in this manner. Such cases have been classified by the amount of antitoxin given by this route, only within 12 hours of admission. The groups and their respective mortalities are given in Table I.

The mortality for the untreated group approximates that of the whole

* Based upon a thesis submitted to the Faculty of the Yale University School of Medicine in candidacy for the degree of Doctor of Medicine, June, 1933.

† In most instances the dose cited was given within six hours of admission. In the few cases which developed in a hospital, the figures are for treatment given within 12 hours of the first symptoms. Submitted for publication April 17, 1936.

TABLE I

MORTALITY IN UNTREATED CASES, AND IN GROUPS CLASSIFIED ACCORDING TO TREATMENT

Groups	Total Antitoxin within 12 hrs.	Inthrathecal Antitoxin within 12 hrs.	Cases	Deaths	Mortality Per Cent
A	None	None	72	47	65.3
B	Less than 10,000 U	None	116	68	58.6
C	10,000 U or more	None	112	74	66.1
D	Not specified	Less than 2,000 U	74	47	63.5
E	Not specified	2,000–9,000 U	107	70	65.4
F	Not specified	10,000 U or more	161	99	61.5
Totals			642	405	63.0

series, and there are no significant differences among the several groups. Nearly all the patients who received intrathecal antitoxin received large intravenous and intramuscular doses in addition. Of the patients not treated intrathecally, many of those (Group C) received very large amounts of antitoxin within the stated time. All but six of these patients received at least 20,000 units within 12 hours after hospitalization. From these data it is evident that small or large doses of antitoxin have little effect on the mortality.

The figures generally cited as evidence for the therapeutic value of diphtheria antitoxin are those correlating early treatment and low mortality. However, in the study of these tetanus cases it soon became evident that the mortality was highest in patients admitted to the hospital within 24 hours of the first symptoms, in both the untreated and treated groups. In Table II the entire series is analyzed according to two prognostic criteria, the incubation period, and the time between the onset of symptoms and hospitalization. The correlation between the two is interesting.

It will be seen that in the cases of patients admitted on the first day the incubation period is usually short. Both the incubation period and the duration of symptoms to admission must be considered in evaluation of the prognosis, but the latter seems actually the more important. This observation does not mean that early treatment was harmful. It merely shows that the rapidity with which symptoms progress is an important factor in the prognosis. Patients whose symptoms compel them to seek hospitalization within 24 hours of the onset of the disease are patients with severe tetanus. However, these figures confirm the belief that the effect of antitoxin treatment cannot be great.

Since serum treatment, if effective at all, should be chiefly so on the first day of the disease, it seemed desirable to select from the treated and untreated groups cases of patients admitted within this interval whose incubation periods were comparable. The figures are given in Table III.

Here again it is clear that treatment is not associated with a marked diminution of mortality. There is a slight difference in favor of the patients

TABLE II

AN ANALYSIS OF THE OUTCOME IN 642 CASES OF TETANUS, WITH REFERENCE TO INCUBATION PERIOD, AND THE DURATION OF SYMPTOMS OF TETANUS UP TO THE TIME OF HOSPITALIZATION

Day of Disease on Which Patient Was Admitted

Incubation	1		2		3		4		5		6 &+		Uncertain*		Total	
(days)	D	R	D	R	D	R	D	R	D	R	D	R	D	R	D	R
0–7.....	98	10	34	8	8	1	2	8	0	0	1	6	17	3	158	36
8–14.....	45	15	33	17	12	15	10	11	0	1	2	15	25	5	127	79
15–21.....	7	6	7	6	5	5	2	6	1	3	1	15	7	4	30	45
More than 21..	3	0	3	4	1	4	3	1	0	1	0	1	2	1	12	12
?.....	27	5	9	4	14	11	4	12	3	7	7	20	12	6	78	65
Total	180	36	86	39	40	36	21	38	4	12	11	57	63	19	405	237

D = deaths. R = recoveries.

* This column includes cases in which the duration of symptoms was not stated in the history, and the few cases which developed in a hospital.

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TABLE III

CASES OF PATIENTS ADMITTED ON FIRST DAY OF SYMPTOMS OF TETANUS

Group	Incubation 0–7 Days			Incubation 8–14 Days		
	Cases	Deaths	Mortality	Cases	Deaths	Mortality
A.....	11	11	100.0%	1	1	100.0%
C.....	15	14	93.3%	15	13	86.7%
A–D incl.....	57	54	94.7%	36	30	83.3%
E and F.....	51	44	86.3%	24	15	62.5%

receiving over 2,000 units intrathecally. This difference is barely twice the calculated standard deviation;[6, 7] such a difference is classed as "probably significant" by some statisticians. However, unqualified "significance" is attributed only to differences of a magnitude at least three times that of the standard deviation. The present data might be interpreted as a corroboration of the experimental data in favor of intrathecal treatment, but their evidential value is slight.

TABLE IV

MORTALITY IN PATIENTS ADMITTED ON FIRST DAY OF SYMPTOMS, WHOSE INCUBATION PERIODS WERE NOT LONGER THAN 14 DAYS

Comparison of Groups A–D with Groups E–F

Groups	Cases	Deaths	Mortality
A–D.....	93	84	90.3%
E–F.....	75	59	78.7%
Difference.....			11.6%
Calculated Standard Deviation...			5.5%

The figures given there confirm those of previous workers,[2, 3] and indicate that relatively little has been accomplished in the specific treatment of tetanus. Further work may confirm or deny the suggestion as to the desirability of intrathecal treatment. It is hoped that the data in Table II may be of value as a control for further therapeutic experiments. At present it would seem that adequate sedation was the most hopeful line of attack.

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[1] Data were collected from the following hospitals: in Boston, Children's, Massachusetts General, Boston City; in Hartford, Conn., Hartford Hospital; in New Haven, Conn., New Haven Hospital; in New York, Presbyterian, Babies', Roosevelt, Mt. Sinai, Bellevue; in Philadelphia, University of Pennsylvania, Children's, Episcopal, Jefferson, Presbyterian; in Baltimore, Johns Hopkins, University of Maryland; in St. Louis, Barnes and St. Louis Children's.

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ACUTE SUPPURATIVE TENOSYNOVITIS OF THE FLEXOR TENDON SHEATHS OF THE HAND

A REVIEW OF ONE HUNDRED AND TWENTY-FIVE CASES

ROBERT S. GRINNELL, M.D.

NEW YORK

FROM THE DEPARTMENT OF SURGERY, COLLEGE OF PHYSICIANS AND SURGEONS, COLUMBIA UNIVERSITY, AND THE PRESBYTERIAN HOSPITAL, NEW YORK, N.Y.

INFECTIONS of the flexor tendon sheaths of the hand present a problem still far from solution. They are of importance because of their frequency, their notoriously poor results, and the likelihood of permanent disability. Little progress has been made in their treatment in recent years. Surprisingly few large series of cases have been reported in the literature with enough follow up reports to give a true picture of the end-results. The most comprehensive reviews in the past have been those of Forssell[1] (1903), Keppler[2] (1912), Cleveland[3] (1924), Garlock[4] (1924), Schiessl[5] (1925), Brofeld[6] (1929), and Deike[7] (1933). In most of these, however, the follow up results were scanty. This review is an attempt to supply that defect. The series includes 125 cases admitted to the wards of this hospital over a 17 year period from 1916 to 1933. The average period of observation after operation was 16 months. A few cases were omitted because of insufficient data or because of an inadequate follow up report. During this period there were seven cases of gonococcus tenosynovitis which were not included in this analysis and which will be discussed only briefly.

Origin of Infection.—Infection may reach the sheath by any one of four routes. It may be introduced by primary direct inoculation as by a puncture wound, by secondary extension from a neighboring infection, by the blood stream, or by lymphatic spread from a more distant focus. None of the cases was infected by the hematogenous route except the seven gonococcus infections which will be discussed separately. Lymphatic involvement of a sheath from a distance must be rare. In spite of a careful search no instance of it was found in this series. Kanavel[8] believed it occurred occasionally following a lymphangitis on the volar surface of the finger. Forssell[1] reported three cases of ulna bursitis following a thumb infection, without suppuration of the radial bursa, which he believed were lymphatic in origin. These cases, however, are not very convincing.

As the hematogenous and lymphatic sources of infection can be eliminated here, the cases fall into two main groups, primary and secondary. The primary group represents those cases in which the infection has been implanted directly into the sheath at the time of injury. The secondary group includes those cases in which the sheath was involved by extension from a neighboring infection, usually an overlying abscess. These two groups differ considerably in their characteristics as will be shown by later comparisons. The

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differentiation between them in this review was not always easy but could usually be made fairly accurately from the type and site of injury, the symptomatology, and the findings at operation. There were 67 primary cases, or 54 per cent, and 58 secondary cases, or 46 per cent.

Trauma.—A history of preceding injury was obtained in 92 per cent of the cases. As shown in Table I a puncture wound was by far the most frequent cause, occurring in 64 cases or 51 per cent. The outstanding feature was the insignificant character of the wound in most cases. Not infrequently the injury was so slight that the patient had difficulty in remembering it. Four of the infections were due to human bites and will be discussed more at length later.

TABLE I

TYPES OF INJURY CAUSING TENOSYNOVITIS

	Cases	Per Cent
Puncture wounds	64	51
Lacerations and incised wounds	39	32
Unknown	10	8
Contusions	4	3
Burns	4	3
Human bites	4	3
Totals	125	100

Wound of Entrance.—The frequent origin of tenosynovitis from injury at the flexor creases of the fingers has long been recognized. This series adds further emphasis to this site of origin. In nearly half the cases, 59 or 47 per cent, the wound of entrance was in, or close to, the flexor finger crease. The distal finger crease was the one most frequently involved and was by far the commonest site of entrance of infection anywhere on the fingers or hand. It was involved in 41 instances or 33 per cent in this series. The proximal interphalangeal crease was the site of entry in 13 cases or 10 per cent. At the distal and proximal interphalangeal creases the tendon sheaths are more superficial and are free of the thick annular ligaments which at other points bind them to the phalanges. The absence of this fibrous layer beneath the crease makes free motion possible yet at the same time leaves the sheath more vulnerable to injury and infection. The more frequent involvement of the distal crease may be due to its greater exposure to injury and to the fact that of the three creases it lies closest to the tendon sheath. Only a very slight injury or puncture wound in this region may infect it. The metacarpophalangeal crease was implicated in only 4 per cent of the cases. The tendon sheath beneath this crease is quite superficial but is protected by the phalangeal annular ligament which is absent at the other creases. Cases of tenosynovitis due to injury at the creases were mostly primary infections (68 per cent) from direct inoculation.

Tenosynovitis arising from injury or infection elsewhere than from a finger crease occurred in 63 cases or 51 per cent. The most common site

TABLE II

SITE OF WOUND OF ENTRANCE

Site		Cases	Per Cent
At finger crease	Distal crease	41	33
	Middle crease	13	10
	Proximal crease	5	4
	Totals	59	47
Not at finger crease	Distal closed space	23	19
	Middle closed space	13	10
	Proximal closed space	16	13
	Palm	7	6
	Dorsum of hand or finger	4	3
	Totals	63	51
Unknown		3	2
Totals		125	100

was the distal closed space, occurring in 23 cases or 19 per cent of the series. Twenty-one of these 23 cases were of the secondary type. The proximal and middle closed spaces and the palm were less frequently at fault in the order named. The involvement of the tendon sheath secondarily from the distal closed space is of interest and illustrates the two routes of infection that have been emphasized by Auchincloss.[9] In 10 of the 21 cases in which the sheath was thus involved, the infection apparently invaded the end of the sheath directly from the adjacent soft tissues; in the remaining 11 cases, it reached the sheath by way of the shaft of the distal phalanx, the volar subtendinous space, and the distal phalangeal joint, usually with an osteomyelitis of both the distal and middle phalanges. The frequency of tenosynovitis secondary to infection of the distal closed space emphasizes the importance of early and adequate drainage of these infections.

Site.—The right hand was involved in 67 per cent of the cases, or twice as often as the left. The difference is obviously due to the greater use of the right hand and the greater chance of injury. The incidence of tendon sheath infection in the different fingers is shown in Table III. The thumb, index, and middle fingers were most often affected, probably in direct proportion to their more general use. The index finger came first. Other

TABLE III

DISTRIBUTION OF CASES OF TENOSYNOVITIS IN FINGERS

	Cases	Per Cent
Thumb	22	18
Second finger	44	35
Third finger	33	26
Fourth finger	17	14
Fifth finger	9	7
Totals	125	100

reported series of tenosynovitis show a similar incidence, but with the thumb or third finger in first place.

Age and Sex.—There were 68 males and 57 females. The average age was 37, the youngest being five and the oldest 71.

Diagnosis.—Early recognition of tendon sheath infection is of paramount importance. Failure to recognize it at the outset and the consequent delay in operation are probably the main causes of the prevalent poor results. In 31 cases of this series, or 25 per cent, the diagnosis was not made at the first visit to the hospital. In the group with primary infection the diagnosis was missed in only 13 per cent of the cases, but in the group secondarily infected it was missed in 38 per cent and was often not made until after several days' delay (Table IV). The average delay in operation because of error in diagnosis in the primary group was one day, whereas in the secondary group it was over four days. The difference between the two groups is not surprising. In the primary group the classic signs of tendon sheath involvement are usually clear cut. The presence of tenderness localized definitely to the region of the sheath, the flexed position of the finger, and the exquisite pain on passive extension of the distal phalanx, are signs which leave little doubt as to the diagnosis. Of these, localized tenderness over the sheath is by far the most reliable. A wound of entry over the course of the sheath is usually present also. Usually these signs are easy to elicit, except in cases with a partially draining sheath in which they may be obscured because of lack of tension of the exudate in the sheath. Such cases are not an infrequent source of error in diagnosis. In the secondary group the diagnosis is more difficult. Here the presence of infection in the tissues outside the sheath confuses the picture. It is often difficult to decide whether or not the sheath has been invaded, especially in those cases in which only a localized portion of the sheath has been involved, as not infrequently happens. It should be strongly emphasized, however, that when the diagnosis of suppurative tenosynovitis is in doubt, it is usually better to operate than to delay. This point will be discussed subsequently in greater detail.

TABLE IV

ACCURACY OF DIAGNOSIS IN PRIMARY AND SECONDARY CASES AND IN WHOLE SERIES

	Primary		Secondary		Totals	
	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent
Correct diagnosis.....	58	87	36	62	94	75
Incorrect diagnosis.....	9	13	22	38	31	25

Classification of Results.—The results in this series of 125 cases were based on an average follow up period of 16 months. In evaluating the end-results, anatomic, symptomatic, and economic factors were considered, but the chief emphasis was placed upon the functional result. The classification into four groups used by Cleveland[3] was adopted with slight modifications.

Group I.—Bad Results.—This group included deaths, amputations, and deformed, stiff, often painful fingers without motion at the interphalangeal joints and little at the metacarpophalangeal joint.

Group II.—Fair Results.—Nearly complete motion at the metacarpophalangeal joint but no active motion at the interphalangeal joints.

Group III.—Good Results.—Complete function at the metacarpophalangeal joint and slight active motion at the interphalangeal joints.

Group IV.—Optimal Results.—An almost complete return of normal function in the finger. There may be very slight limitation of extreme flexion or extension but the finger is practically as useful as before the infection.

Results.—The final results in the 125 cases of this series were discouraging. Over one-third of all the cases fell into Group I. Nearly two-thirds of the cases were in Groups II and III. Only one-sixth regained approximately full function (Table V). These results were similar to those of

TABLE V

A COMPARISON OF RESULTS BY GROUPS

	Group I Bad Results		Group II Fair Results		Group III Good Results		Group IV Optimal Results		
	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent	Totals
Present series.....	44	35	31	25	29	23	21	17	125
Present series (15 cases with tendon necrosis at operation omitted)	34	31	28	25	27	25	21	19	110

Cleveland,[3] whose 57 cases from this hospital were included in the present series. As it seemed perhaps unfair to include very advanced cases, another summary was made omitting 15 cases which showed definite necrosis of the tendon at operation. These results, however, were only slightly better. Other reported series show varied figures. Keppler,[2] Schiessl,[5] and Deike[7] classified their cases according to function into three groups—good, average, and poor. An attempt was made to reclassify our results for comparison. They proved to be very similar to those of Deike, but much poorer than those of the other two authors (Table VI). Perhaps the discrepancy can be partly explained by differences in follow up methods. Schiessl did not

TABLE VI

A COMPARISON OF RESULTS WITH THOSE IN OTHER SERIES

Reclassified into Three Groups

	Poor		Average		Good		Totals
	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent	Cases
Keppler (1912).....	35	28	13	10	79	62	127
Schiessl (1925).....	19	28	10	14	39	57	68
Deike (1933).....	106	53	34	17	60	30	200
Present series (regrouped).....	63	50	27	22	35	28	125

state whether his cases were followed or not. Keppler reexamined about one-half of his cases but did not state the length of follow up. Deike followed only one-third of his series, largely by questionnaire. The cases reported here were followed for an average period of 16 months after operation by actual interview and examination in nearly every case.

Tendon Necrosis.—Gross sloughing of the tendons in whole or in part was very frequent and was noted in 52 per cent of the cases. It was possibly even more frequent but was not recorded. Deike[7] noted it in about one-fourth of his 200 cases. Garlock[4] reported necrosis of the tendon or tendon sheath in 72 per cent of his 42 cases. A comparison between the incidence of tendon slough and the results showed a close correlation between the two. The one case in Group IV showing tendon necrosis was one in which a small portion of the flexor carpi radialis tendon sloughed, leaving no perceptible loss in function. Of the five cases in Group I without tendon slough, four had stiff contracted fingers and one died of sepsis (Table VII).

TABLE VII

INCIDENCE OF TENDON NECROSIS IN THE RESULT GROUPS

	Group I Bad Results		Group II Fair Results		Group III Good Results		Group IV Optimal Results		Totals	
	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent
Tendon intact...	5	11	14	45	21	72	20	95	60	48
Tendon sloughed.	39	89	17	55	8	28	1	5	65	52

Necrosis of the tendon was slightly more frequent in secondary than in primary infections, occurring in 55 per cent of the former and 40 per cent of the latter. The infection in the soft tissues outside the tendon sheath, which is present in secondary cases, tends to prolong the infection within the sheath and compromise the tendon.

As later discussion will show, tendon necrosis occurred with about equal frequency in Staphylococcus and Streptococcus infections but much more frequently in mixed infections with two or more organisms.

Bacteriology.—Culture reports were obtained in all but 13 cases. With but few exceptions these were taken at operation. Further cultures were rarely taken. It is probable that secondary contamination with other organisms frequently occurred later and may have influenced the course of the infection. The Streptococcus hemolyticus was the organism most frequently found, and was present in pure culture at operation in 45 cases (36 per cent), and the Staphylococcus in 39 cases (31 per cent). The remaining 28 cases included 13 cases of mixed Streptococcus hemolyticus and Staphylococcus, eight cases in which no growth was reported, five cases of mixed organisms, three of which contained *B. coli*, and two cases of nonhemolytic streptococcus in pure culture. Keppler's[2] series showed a very similar distribution of organisms. In most of the other reported series, however, few if any cultures were reported.

The results were definitely better in the Staphylococcus than in the Streptococcus cases. The mixed Streptococcus hemolyticus and Staphylococcus cases held an intermediate position and appeared to do slightly better than the Streptococcus cases in pure culture but were too few in number for fair comparison. The other instances of mixed infection did poorly. A number of these were very late cases. Those in which no growth was reported did unusually well. Some were very early cases and several may have been unrecognized cases of gonococcus tenosynovitis. The 13 cases in which no culture report was received did extremely poorly (Table VIII). Some were late, advanced cases in which the culture was neglected. The poorer prognosis in the Streptococcus cases is somewhat surprising. Keppler[2] and Cleveland[3] noted this also. This group, however, included most of the very severe spreading infections and most of the bad complications.

TABLE VIII

A COMPARISON OF RESULTS ACCORDING TO BACTERIOLOGY

	Group I Bad Results		Group II Fair Results		Group III Good Results		Group IV Optimal Results		Totals	
	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent
Streptococcus hemolyticus	19	42	13	29	8	18	5	11	45	36
Non-hemolytic streptococcus	—	—	1	50	—	—	1	50	2	21
Staphylococcus	10	25	8	21	13	33	8	21	39	3
Streptococcus hemolyticus and Staphylococcus	5	38	2	16	5	38	1	8	13	10
Miscellaneous	3	60	2	40	—	—	—	—	5	4
No growth	—	—	1	12	2	25	5	63	8	7
No report	7	54	4	30	1	8	1	8	13	10
Totals	44	35	31	25	29	23	21	17	125	100

The incidence of tendon slough was about the same in both the Streptococcus hemolyticus and Staphylococcus groups. It was much higher in cases of mixed infection with two or more organisms (Table IX).

TABLE IX

A COMPARISON OF THE INCIDENCE OF TENDON NECROSIS WITH BACTERIOLOGY

	Tendon Intact		Tendon Sloughed		Totals	
	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent
Streptococcus hemolyticus	25	56	20	44	45	36
Non-hemolytic Streptococcus	1	50	1	50	2	2
Staphylococcus	21	54	18	46	39	31
Streptococcus hemolyticus and Staphylococcus	5	38	8	62	13	10
Miscellaneous	—	—	5	100	5	4
No growth	7	88	1	12	8	7
No report	1	8	12	92	13	10
Totals	60	48	65	52	125	100

The Streptococcus was found more often in primary tenosynovitis than the Staphylococcus. Sixty-nine per cent of the Streptococcus cases were of this kind as compared to 44 per cent of the Staphylococcus cases. Similarly, the Staphylococcus was more frequently present in secondary tenosynovitis.

The exact importance of secondary contamination was not determined. To do this repeated cultures in each case would have been necessary. Its importance, however, is undoubtedly great. Since 1921, especial care was taken in the early dressings to prevent it. The hand and forearm were kept in sterile towels. Dressings were touched only with sterile gloves or instruments. If soaks were used every precaution was taken to keep them sterile as well.

Primary and Secondary Tenosynovitis.—This analysis has already shown that secondary tenosynovitis is more difficult to diagnose and more prone to tendon necrosis than primary tenosynovitis. It is most frequently due to the Staphylococcus whereas primary infections are usually due to the Streptococcus. Further analysis will show that secondary tenosynovitis is more apt to cause a localized type of infection with only a partial involvement of the tendon sheath. Contrary to expectation, a comparison between results in primary and secondary tenosynovitis did not show great differences. Both Cleveland[3] and Iselin[10] have stressed the better prognosis in primary cases. In this series the high incidence of primary cases in Group I was due largely to severe Streptococcus infections which were mainly primary. These were offset, however, by a large number of secondary cases in Group I due to late diagnosis and operation, often with extensive infection adjacent to the sheath. The good showing of the secondary cases in Group III was due largely to the inclusion here of secondary cases with only limited sheath involvement and consequently only slight disability. The larger number of primary than secondary cases in Group IV suggests that the best results can be expected in primary cases treated early.

Results in the Different Fingers.—A comparison of the results of tenosynovitis in the various fingers is of interest in showing that the best results occurred in the thumb and the poorest in the fifth finger. If the results in both Group III and IV are combined, the thumb ranks first in spite of the fact that the radial bursa was involved in every case but one and in spite of the frequent extension of the infection to the ulna bursa. When the infection was limited to the digital sheath and radial bursa, the results were unusually good with eight of the 13 cases falling into Group III. When the infection extended to the ulna bursa, however, the results were all very poor. Seven of the eight cases with this extension had to be placed in Group I. The remaining one had fair function, but only because the extension was limited to the ulna bursa above the wrist. Thus, notwithstanding the danger of ulna bursitis, the results in the thumb were better than in the other fingers. Deike[7] obtained his best results in the fourth finger. The thumb ranked low because of the very high incidence of ulna bursa extension in his cases. The better prognosis in the thumb is due to several factors. Since the thumb has

one less phalanx than the other fingers, a sloughed or adherent tendon causes less functional disability. There is loss of motion in the phalangeal joint only, as other muscles provide motion in the metacarpophalangeal joint. The thumb has also only one flexor tendon in its sheath instead of the two present in the other fingers, which often become adherent to each other after infection. The tendon to the thumb lies for most of its course at a deeper level than the other tendons and is less apt to become attached to the skin after incision. Moreover, involvement of the radial bursa in the palm and above the wrist does not usually cause much additional disability unless the tendon sloughs.

In the fifth finger, the results were poor. This finger has none of the advantages of the thumb. Moreover, it has an extensive sheath which includes the tendons of the three middle fingers and which if infected may cripple them as well. Deike also had his poorest results in this finger (Table X).

TABLE X

END-RESULTS IN THE DIFFERENT FINGER SHEATHS

	Group I Bad Results		Group II Fair Results		Group III Good Results		Group IV Optimal Results		Totals	
	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent
Thumb.....	8	36	3	14	9	41	2	9	22	18
Second finger....	16	35	12	27	9	20	8	18	45	36
Third finger.....	11	45	7	21	5	15	10	30	33	27
Fourth finger....	6	37.5	4	25	6	37.5	—	—	16	12
Fifth finger.....	4	44.5	4	44.5	—	—	1	11	9	7

The Bursae.—The radial bursa was involved alone without associated infection of the ulna bursa in 13 cases. In six the whole bursa and digital sheath of the thumb were involved, and in seven cases the digital sheath and bursa in the palm were infected without extension above the wrist. In only one case was the digital sheath of the thumb involved alone without extension upward to the bursa. The bursa was never found infected without the digital sheath. Forssell did not find it to have occurred in his cases or in any of those in the literature. Anatomic studies help to explain this. According to Poirier,[12] the sheath communicates freely with the bursa in 95 per cent of cases. The organisms responsible for these infections were well distributed among the different groups with the Streptococcus hemolyticus the most frequent. As has been shown, the results were surprisingly good with most of the cases falling into Group III. The failure of the infection to extend to the bursa above the wrist in more than half the cases is of interest. I know of no anatomic explanation. It was probably due to the walling off of the sheath by exudate ahead of the infection.

The ulna bursa was involved alone without associated radial bursitis in eight cases. In three the infection included the fifth finger sheath and the

whole bursa, in three cases it affected the finger sheath and the bursa in the palm only, and in two cases it involved the bursa in the palm and above the wrist without the digital sheath. In two cases the fifth finger sheath was involved without any extension to the bursa. The frequent infection of the digital sheath or bursa without the other may be partly explained on anatomic grounds. Poirier found full communication in only about one-half of his dissections. The others showed either narrowing or complete occlusion. Half of the ulna bursa cases in this series were caused by the Streptococcus hemolyticus in pure culture. The results were nearly all very poor.

There were ten instances of combined infection of both radial and ulna bursae. These infections are notorious for their severity, rapid spread, and crippling results. Most of the major complications occurred in this group. In nine of these cases the infection spread from the radial to the ulna bursa and in only one did it spread from the ulna to the radial bursa. The frequent extension of the infection from one bursa to the other may be due to actual communication or to their proximity. Poirier found free connection to occur in about one-half of his dissections, usually by way of one or two small intervening bursae. In our series 41 per cent of the radial bursitis cases spread to the ulna bursa and only one case of ulna bursitis spread in the reverse direction. Other authors report a higher incidence. Forssell,[1] Brofeld,[6] and Deike[7] had 85, 76, and 43 per cent respectively of radial to ulna bursa extensions, and 21, 0, and 35 per cent of ulna to radial bursa extensions. Brofeld encountered no instance of ulna-radial bursa spread. The more frequent extensions in these series may be due to a larger number of late neglected cases. The preponderance of spread from the radial to the ulna bursa as compared to that in the reverse direction is noteworthy and has been reported by other authors. No satisfactory explanation, however, has been offered. The involvement of the bursae and finger sheaths was complete in all but two cases. The Streptococcus hemolyticus was present in every case but one. In seven it was recovered in pure culture and in two cases it was combined with the Staphylococcus. This is the organism one would expect in such virulent and wide spread infections. The results were extremely bad. Every case but one fell into Group I.

TABLE XI

RESULTS IN RADIAL AND ULNA BURSAE

	Group I Bad Results		Group II Fair Results		Group III Good Results		Group IV Optimal Results		Totals
	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent	Cases
Radial bursa	1	8	2	15	8	62	2	15	13
Ulna bursa	3	38	4	50	—	—	1	12	8
Radial and ulna combined	9	90	—	—	1	10	—	—	10

Duration of Tenosynovitis Before Operation and Results.—The average duration of tenosynovitis before operation was 6.2 days. This long period of delay was probably the chief cause of the poor end-results. The average delay before operation in Group IV was 3.4 days as compared to 9.3 days in Group I. This delay was due in part to errors in diagnosis in our own Out-Patient Clinic, but chiefly to delay before coming to the Clinic. A comparison of the cases without tendon necrosis with those with necrosis also showed the importance of the time factor. The average duration of symptoms in the former was 3.6 days as compared to 8.3 days in the latter. The time factor is not, however, the only one; some cases operated upon within 24 hours of the beginning of the infection did badly and others incised after days of delay had nearly perfect function. But these were the exceptions.

TABLE XII

AVERAGE DURATION OF TENOSYNOVITIS BEFORE OPERATION IN THE RESULT GROUPS

	Group I Bad Results	Group II Fair Results	Group III Good Results	Group IV Optimal Results	General Average
Average days duration before operation.....	9.3	5.0	4.6	3.4	6.2

Age and Results.—The effect of age on the results and on the incidence of tendon necrosis was also studied. Cases with poor results tended definitely to fall into an older age group than those with good results. The average age of the cases in Group IV was 30 years as compared to 42 years in Group I, an average difference of 12 years. The frequency of tendon slough also increased with age. Thus the average age of patients without tendon necrosis was 32 years as compared to 42 years among those with necrosis (Table XIII). Patients who developed complications were also slightly older on the average. Those with severe infections such as combined radial and ulna bursa involvement had an average age of 44 years as compared to the general average of 37. Deike,[7] Forssell,[1] zur Verth,[11] and Kanavel[8] likewise emphasized the poorer prognosis in older patients and the greater frequency of sepsis and other complications among them. Deike even claimed that his favorable results only occurred in patients under 30 years of age. Moissejeff[13] attributed this phenomenon to increasing atherosclerotic changes in the tendon in later life.

TABLE XIII

RELATION OF AGE TO TENDON NECROSIS AND END-RESULTS

	Tendon Intact	Tendon Sloughed	Group I Bad Results	Group II Fair Results	Group III Good Results	Group IV Optimal Results
Average age (years)	32	42	42	37	31	30

Recent Versus Older Results.—A comparison of results of cases operated upon in the decade from 1916 to 1925, as compared to a nearly equal number in the eight years from 1926 to 1933 inclusive, was disappointing (Table

XIV). It showed only slight improvement in the more recent group in spite of a campaign for earlier diagnosis, earlier removal of drains, and a more rigid aseptic dressing technic, designed to prevent secondary contamination. The results are still very poor and allow of much greater improvement.

TABLE XIV

A COMPARISON OF RESULTS IN THE 10 YEAR PERIOD (1916–1925) AND 8 YEAR PERIOD (1926–1933)

	Group I Bad Results		Group II Fair Results		Group III Good Results		Group IV Optimal Results		Totals	
	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent
1916–1925.....	24	40	15	25	12	20	9	15	60	48
1926–1933.....	20	31	16	25	17	26	12	18	65	52

Soaks Versus Moist Dressings.—An attempt was made to compare results according to the type of treatment used after operation. This was found to be difficult because of the wide variety of procedures and the frequent shift from one treatment to another. The chief difference was found to be in the use of sterile hand soaks of saline or boric solution as compared to the use of sterile gauze compresses which were moistened frequently with these solutions without disturbing the dressing. The soaks were given for about 30 minutes every three or four hours. Large deep basins were used in which the whole hand and forearm could be immersed to above the elbow. A third group included those cases in which neither of the above procedures had been carried out consistently and in which Dakin's solution was also frequently used. These were usually late neglected cases.

The results seemed to show the wet dressing procedure to be preferable to the soaks (Table XV). Using the presence or absence of tendon slough as a criterion, the advantage seemed to rest also with the wet dressings. The arguments advanced for the soaks are that they allow earlier finger motion and better cleansing of the wounds. Against them is the difficulty of preventing secondary contamination and the impossibility of maintaining elevation of the hand while in the soak, with consequent congestion of the tissues. It should be emphasized again, however, that, because of the many variable factors and the short duration of the procedure in many cases, the comparison is open to question.

TABLE XV

COMPARISON OF RESULTS BETWEEN CASES TREATED WITH WET DRESSINGS AND HAND SOAKS

	Group I Bad Results		Group II Fair Results		Group III Good Results		Group IV Optimal Results		Totals	
	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent
Wet dressings...	9	26	7	21	8	24	10	29	34	27
Hand soaks.....	26	34	22	29	18	24	10	13	76	61
Miscellaneous...	8	53	4	27	2	13	1	7	15	12

Complications.—There was only one death in this series, a percentage of 0.8. This was a case of Streptococcus hemolyticus infection involving the radial bursa and spreading to the forearm. The patient developed a positive blood culture on the fifth day after operation and died the next day, following a severe hemorrhage from the radial artery. Other authors have found the mortality higher. Klapp,[14] Keppler,[2] and zur Verth[11] had an incidence of between 3 and 5 per cent. Deike[7] had 16 deaths in 200 cases, or a mortality of 8 per cent. These were mostly in old people with sepsis.

Amputation of an arm or finger was performed in 11 cases or 8 per cent. Eight were finger amputations and were thought advisable because of extensive tendon slough and osteomyelitis in six cases and for severe contractures in two cases. One amputation through the midforearm and two through the upper arm were performed because of severe infection. One of the latter was accompanied by recurrent hemorrhage from the radial artery. A stiff finger, if ankylosed in the optimum position of slight flexion, is usually useful; although the two distal phalangeal joints are frequently stiff, the metacarpophalangeal joint usually has some motion. Such a finger is frequently preferable to an amputated stump. The thumb should never be amputated.

Osteomyelitis was a common complication and occurred in 47 cases or 38 per cent, and was often multiple. The middle phalanx was the one most frequently infected, chiefly because of its central position and frequent involvement with a suppurative arthritis of either the proximal or distal phalangeal joint. This bone was involved in 28 cases. Suppurative arthritis was also frequent and occurred in 36 cases or 29 per cent. The distal phalangeal joint was the joint most often invaded. Not only was it involved secondarily to the sheath but it was often the route by which infections of the distal closed space reached the sheath. The proximal phalangeal joint was the joint most often affected secondarily to infection of the tendon sheath. The metacarpal bone and the metacarpophalangeal joint were the least often involved. The Staphylococcus in pure culture was responsible for slightly more cases than the Streptococcus (40 per cent as compared to 26 per cent), and was more prone to involve several bones before the infection was arrested. The results in this group, with complicating osteomyelitis and suppurative arthritis, were very poor, as would be expected, and most of the cases fell into Group I. The figures for the incidence of osteomyelitis and arthritis are open to some question but are approximately correct. It was difficult to be sure of the actual involvement in all cases.

Hemorrhage from the radial artery occurred in two cases. One was associated with severe infection and was largely responsible for the patient's death. The other also accompanied a severe infection and recurred several times, finally necessitating upper arm amputation. In the former the use of Dakin's solution and hard rubber tube drains close to the radial artery may have contributed to the hemorrhage. In both these cases the radial bursa above the wrist had become involved and was drained by a lateral incision

between the flexor carpi radialis tendon and the artery. This incision is more anterior than the one usually made behind the artery and may leave it more exposed to trauma and infection. Kanavel, Deike, and Garlock reported similar complications. Deike and Kanavel had several cases of severe hemorrhage from the ulnar artery as well. Kanavel believes this is the artery usually involved. He emphasizes the danger of severe and even fatal hemorrhage. He believes ligation of the vessel should be done at once and advises against packing the wound or other temporizing measures. Our experience in these two cases confirms his view.

It is of interest that suppurative phlebitis, which occurred only once as a complication, developed in the only case in which Bier's passive hyperemia treatment was tried. This was a toxic case with a severe infection of the radial bursa. Venous constriction was maintained for the first 15 hours after operation by an Esmarch bandage about the upper arm which impeded the venous return but did not obliterate the arterial pulse. A suppurative phlebitis developed later in the median basilic vein and had to be incised. This procedure was formerly extensively used in Germany but in recent years has had fewer supporters. A number of cases of secondary erysipelas have been reported following its use.

There were two cases of gangrene of the terminal phalanx secondary to extensive soft tissue involvement and osteomyelitis. Deike, zur Verth,[11] and others reported similar occurrences in severe and neglected infections due apparently to thrombosis of the vessels in the finger. Deike had ten such cases.

Musculospiral nerve paralysis from the use of an Esmarch tourniquet with temporary wrist drop occurred in two cases. One lasted five months before complete recovery. To prevent this Auchincloss uses at least 18–20 layers of towelling beneath the tourniquet.

One boy, age 8, developed a positive Staphylococcus hemolyticus blood culture after operation and a metastatic osteomyelitis of the femur that had to be drained. Deike had five similar cases, all with foci in the bones of the lower extremity. All of his cases died. In only three of our cases was sepsis proven by positive blood cultures. One has just been mentioned; and of the other two, both due to the Streptococcus hemolyticus, one recovered and the other died following hemorrhage from the radial artery.

It is significant that the Streptococcus hemolyticus was the organism present in most of the cases with severe complications. It was responsible for the only death, all of the upper arm and forearm amputations, two of the eight finger amputations, both cases of secondary radial artery hemorrhage, both cases of local gangrene of the terminal phalanx, the only case of suppurative phlebitis, seven of the nine cases with extension into the spaces of the forearm, four of the five cases of extension to the tendon sheath of the flexor carpi radialis muscle, and the only case with extension to the wrist joint.

Other complications such as involvement of the forearm, the tendon sheath

of the flexi carpi radialis muscle, and the wrist joint will be discussed later with the other extensions of tenosynovitis.

Human Bite Infections.—There were three cases of tenosynovitis secondary to human bites on the dorsum of the hand. In all, the sheath was involved by way of the metacarpophalangeal or interphalangeal joint, and the volar subtendinous space. In only one was the extension of the process to the sheath recognized before the infection was well advanced. All these cases showed extensive tendon slough, osteomyelitis, and suppurative arthritis. In two the finger was amputated. In the third it was advised but not done. The results were all bad. Probably because of the mixed and virulent organisms introduced, these cases are notoriously persistent and disabling. Kanavel and Mason and Koch[15] have recently discussed them at length. Every human bite should be treated with extreme consideration and in most cases admitted to the hospital at once. Mechanical cleansing of the wound should be carefully carried out. Some débridement may be necessary. Incisions should be liberal. Extension to the bones and joint should be watched for and treated accordingly. Unless drainage is adequate there is danger of further extension to the flexor tendon sheath. Because of the presence of anaerobic organisms in the mouth, particularly anaerobic streptococci, spirochaetes, and fusiform bacilli, Meleney[16] advises débridement and flooding of all surfaces of the wound with a creamy suspension of zinc peroxide. This suspension is also used at subsequent dressings.

Extensions of Tenosynovitis.—Extensions of the infection from the sheath to the fascial spaces of the hand occurred frequently. The thenar space was involved in 15 cases: in ten from the second finger, in three from the first finger, in one from the third finger, and once from the fourth finger via the midpalmar space. The midpalmar space was involved four times: once following infection of the third, fourth, and fifth finger sheaths respectively and once following an infection of the palm. The space between the first dorsal interosseus and adductor transversus pollicis muscles was involved four times as a complication of tenosynovitis of the first and second fingers. In three cases it was associated with an abscess of the thenar space and was apparently secondary to it. In one case the thenar space was apparently not involved. These extensions were similar to those described by Kanavel and Deike.

Extension of infection into the soft tissues of the forearm occurred in nine cases. It followed involvement of the radial bursa above the wrist and combined infection of both bursae above the wrist in three cases each. It occurred once after involvement of the ulna bursa alone, and twice from extension of an infection of the thenar space. In no instance did it follow midpalmar space infection. Most of these were markedly toxic cases. The forearm extension in itself added little to the later disability. Six of the cases showed Streptococcus hemolyticus in pure culture, one showed Streptococcus hemolyticus and Staphylococcus, and in the remaining two there was no culture report. Other authors emphasize also the frequency of forearm infection

following radial or ulna bursitis. Deike had 61 cases. All agree that it occurs rarely after thenar space, and almost never after midpalmar space involvement. The best approach to these deep forearm abscesses has been recently discussed by Auchincloss.

Extension to the tendon sheath of the flexor carpi radialus muscle occurred in five instances. In every case it followed involvement of the radial bursa in the palm and above the wrist. In one of these the infection spread from the flexor carpi radialis sheath to the wrist joint and extended between the trapezoid and the second metacarpal bone to the dorsal subaponeurotic space. The patient recovered but was left with a stiff hand and wrist. This was the only case in this series with wrist joint involvement. The Streptococcus hemolyticus was present in the culture of four of the five cases, including the one spreading to the wrist joint. Disability from involvement of the sheath of the flexor carpi radialis muscle was very slight. Involvement of the wrist joint, however, is always a serious complication often necessitating amputation. Deike had four cases, of which one died, two had amputations, and one has a stiff, crippled hand. Both Auchincloss and Deike believe that the usual route of involvement is from the radial bursa to the sheath of the flexor carpi radialis tendon which inserts into the bases of the second and third metacarpal bones.

Extensions from the volar to the dorsal surface of the hand occurred in ten cases. In six of them the route was by way of the lumbrical muscles and the webs. In four instances it led through the joints; once in the proximal phalangeal, twice in the metacarpophalangeal, and once through the carpus. Extension in the reverse direction, from the dorsum to the volar side of the hand, occurred in only three cases. These were all human bite infections, spreading by way of the metacarpophalangeal joint twice and the proximal phalangeal joint once. These cases emphasize the importance of these two routes of deep infection from one side of the hand to the other. Other routes must be very rare. In the fingers the insertion of the deep fascia to the sides of the phalanges and to the skin laterally, tends to prevent spread around the finger by way of the subcutaneous tissues.

Surgical Technic.—The incisions were usually multiple, short, and anterolateral, over the proximal and middle closed spaces in the fingers and a single midline incision over the sheath in the palm. The bursae above the wrist were usually drained by lateral incisions as advocated by Kanavel. The finger incisions were either bilateral or unilateral, and were often given a slight L extension at their distal end for better drainage. Finger incisions lateral to the anterior digital vessels have not been used as they would divide the branches from the vessels to the sheath and tendon and might compromise their nutrition. In only a few advanced cases, with frankly sloughtendons, was a long midline anterior incision across the flexion creases used. Recently Auchincloss has suggested the use of truncated flaps for the finger incisions, one for the proximal and one for the middle closed space. The flap includes all tissues down to the tendon sheath. Its distal end is cut

along the flexion crease. Its sides are cut obliquely to avoid the anterior digital vessels and nerves and extend nearly to the next proximal crease. Its advantage is the better drainage of the sheath. The palmar incision is made as formerly. Ten cases of this series have been incised by this technic with encouraging results. The number is of course too small from which to draw conclusions but the results have been somewhat better than the general average. For deep abscesses extending upward into the interflexor space of the midforearm, the incisions advocated by Auchincloss have been recently used.

Splitting of the anterior carpal ligament, to provide better drainage for suppurative ulna bursitis, was performed on three occasions. These were all advanced cases in which palmar and lateral incisions above the wrist had already been made. All gave poor functional results. Forssell advocated this incision to prevent pressure on the tendons beneath the ligament which he believed was the chief cause of their necrosis. Leibovici and Iselin,[17] on the other hand, condemn this incision. They believe it exposes the tendons without draining the sheath behind them and favors necrosis and contractures. Kanavel advises it only in late cases with necrosis of the tendons or in exceptional instances where excessive pressure on the tendons or on the median nerve is feared. Auchincloss divides the ligament occasionally but believes partial division is often sufficient and prevents prolapse of the tendons.

Duration of Healing and Hospitalization.—The average time required from operation to complete healing was 53 days. Cases without tendon necrosis averaged 36 days, and those with necrosis 71 days, or nearly twice as long. The average period of hospitalization was 22 days, 17 days for those without tendon slough and 26 days for those with it.

Localized Tenosynovitis.—In 24 cases, or 19 per cent, the infection proved to be localized to only a portion of the sheath. This limitation was most common in the first and fifth fingers, probably because of the greater length of these sheaths with their associated bursae. In the fifth finger it may have been due occasionally to an anomalous sheath. In seven cases involving the thumb the infection did not extend to the bursa above the wrist. In the fifth finger the localization occurred in different parts of the sheath and bursa. In the other fingers the localization was about equally distributed between portions of the sheaths in the fingers and the palm. A few of these cases may have been incorrectly classed as instances of localized tenosynovitis when they were really very early infections, incised before the inflammation had had a chance to spread throughout the whole sheath. Such errors were probably rare, however. Klapp and Beck[18] believe that the infection is often temporarily checked in the region of the proximal phalangeal and metacarpophalangeal joints and that the entire sheath is usually not involved unless operation is delayed. Since in all but six of our 24 cases with limited involvement the tenosynovitis was definitely of the secondary type, it seems probable that the limited extent of the tenosynovitis was due rather to the tendency of the sheath to wall off the area of its involvement in the face of a slowly invading infection from without.

The incidence of tendon slough in these cases was slightly above that for the whole series and was probably due to the high proportion of secondary cases, which are more liable to tendon slough because of the associated infection outside the sheath. The bacteriologic reports in this group are interesting in that they show a much greater frequency of Staphylococcus over Streptococcus. In fact only four cases showed Streptococcus hemolyticus in pure culture. This emphasizes the more localizing features of the former as compared to the invasive characteristics of the latter. The results in these cases proved to be slightly better than those for the whole series. The advantage of the more limited extent of infection more than offset the greater incidence of tendon necrosis.

Incompletely Drained Tenosynovitis.—In 28 cases, or 22 per cent, the tendon sheaths were not completely incised although the whole sheath was apparently involved at the time of operation. Seventeen of these had to have their inadequate drainage corrected at a later operation. In a few cases the surgeon apparently felt that adequate drainage of the whole sheath was possible through less than the usual number of incisions. In most cases, however, he was misled by the clinical signs to believe that only a portion of the sheath was involved. This occurred especially in very early cases in which the signs were not as yet definite. The most common mistake was failure to drain the palmar portion of the tendon sheath in infections of the second, third, and fourth fingers. This occurred in 13 cases. Failure to drain the radial bursa above the wrist in five instances was the next most frequent error. Of the cases in which the palmar portion of the sheath was not drained there were four with good results and nine with poor results, five of which were later drained in the palm. Cases with adequate incision in the palm, but inadequate incision in the finger, were less frequent and showed about an equal number of good and bad results. From these figures it would seem as if the palmar portion of the sheath was perhaps the most important to drain. For the three middle fingers, Iselin[10] has recently advocated drainage only in the palm. He believes this method drains the dilated proximal part of the sheath where exudate is most apt to collect and avoids injury to the sliding mechanism in the finger. He makes two volar and two dorsal incisions. There were several cases involving the thumb and fifth fingers in which drainage in the finger and palm was successful without necessitating an incision above the wrist. Failure to drain the bursae above the wrist, however, is hazardous because of the danger of extension to the opposite bursa, to the forearm, and even to the wrist joint.

In this group of incompletely drained sheaths, 18 or 64 per cent showed sloughing of the tendon as compared to 52 per cent in the whole series. The end-results in these cases were slightly poorer than those for the whole group.

Uninfected Portions of Tendon Sheaths Contaminated at Operation.—The chief reason for the incomplete incision of sheaths was the belief that the infection was localized and the fear that further incision might contaminate a hitherto uninvolved part. This danger of contamination was accordingly

studied. There were 12 cases in which the sheath infection was definitely localized but in which uninvolved portions were opened at operation. The most frequently uninvolved site in these cases was either the palmar end of the sheath in the three middle fingers or the part of the bursa above the wrist in the first and fifth fingers. Eleven of the 12 cases showed no apparent bad effects from this contamination. The conclusion is that this danger has been overemphasized. When doubt exists as to whether the infection is limited to a part of the sheath or not it is far better to incise the whole sheath even if this may prove to have been unnecessary. There is some difference of opinion as to the best procedure in such cases. Keppler advises making the first incision in the doubtful portion of the sheath and draining the portion definitely infected last. This perhaps lessens the chance of contamination of the uninvolved portion. Kanavel, however, makes his first incision in the sheath where the infection is certain and then carefully incises towards the doubtful portion. The presence or absence of exudate on pressure over the unopened portion of the sheath and the clinical signs before operation help to determine the extent of the incision. This latter method seems preferable. In this way, infections of limited extent are more readily recognized. When real doubt exists, however, it is wiser to incise the whole sheath.

Uninfected Tendon Sheaths Contaminated at Operation.—There is no record of the number of cases wrongly diagnosed as tenosynovitis in which the sheath was incised, found to be uninfected, and remained so. Unless the sheath became infected subsequently the case would not be listed under that diagnosis. There were only four cases in this series which apparently originated in this way. In these instances the incision disclosed no pus within the sheath but some in the subcutaneous tissues close to it. The sheath was undoubtedly contaminated at operation, but would probably have become involved secondarily anyway. Three of these cases showed tendon slough and poor end-results later. In the fourth case the infection remained localized and left the hand with perfect function. This number is surprisingly small and stands in sharp contrast to the large number of cases in which delay from over caution contributed to the poor end-results. It should be emphasized again that when reasonable suspicion of tenosynovitis is present it is far better to incise than to delay. A neglected sheath will give much greater disability than one opened unnecessarily.

Causes of Poor Results.—The end-results have been shown to be poor. Sixty per cent or nearly two-thirds were unsatisfactory and were placed in the lower two groups. Over one-half showed gross tendon slough. I have tried to list the causes of the poor results somewhat in the order of their frequency and importance. Late operation was the chief of these, due not infrequently to delay in diagnosis in our own Out-Patient Clinic but more often to delay before coming to the hospital. Other causes were secondary infection, late removal of drains, incomplete drainage of the tendon sheath, improperly placed incisions, delay in starting active motion of fingers, too early discharge from the hospital, and inadequate supervision of dressings in

the Clinic after discharge. In addition, failure to realize the danger of human bites, neglect of infections of the distal closed space, lack of cooperation on the part of the patient and lowered resistance from associated disease, such as diabetes, should be mentioned. Even when all the causes of poor results were apparently absent, however, the functional result was often poor. The last word has obviously not been said as to the best type of incision, the best method of drainage, and the best postoperative treatment.

Gonococcus Tenosynovitis.—There were seven cases of gonococcus tenosynovitis during this 17 year period which were not included in this series. The diagnosis was made on a positive wound culture in two instances, on a positive smear from the wound in two cases, and on the clinical symptoms, based on the history of an associated polyarthritis, and a positive prostatic smear in the remaining three. All were hematogenous infections. There were two males and five females with an average age of 23. There was no necrosis of the tendon in any case. Healing was uneventful. In one case in which the diagnosis was confirmed at operation by a positive smear from the sheath, the wound was resutured and healed with a perfect functional result. There were no complications. The average time from operation to complete healing was 20 days as compared to 53 days in the cases caused by other organisms. The average period of hospitalization was only 12 days as compared to a general average of 21 days. The results were almost uniformly good. All the cases had nearly perfect function and were classed in Group IV, except one placed in Group III because of slight limitation of motion in the distal phalangeal joint, and one put in Group II because of a slightly adherent tendon.

SUMMARY AND CONCLUSIONS

(1) There were 125 cases of suppurative tenosynovitis in this series followed for an average of over 16 months. Gonococcus tenosynovitis was not included.

(2) Hematogenous infection did not occur in any case. No case was infected from another focus on the hand by way of the lymphatics.

(3) The puncture wound was the most frequent injury causing infection, occurring in 51 per cent of cases.

(4) The flexor finger creases were the most frequent sites of injury causing tenosynovitis, especially the distal crease. A wound at the finger creases should be regarded as a threat to the tendon sheath. The distal closed space was the second most frequent site of origin. Late and inadequate drainage of infections of this space leads frequently to tenosynovitis.

(5) Tenosynovitis was most frequent in the first three fingers of the right hand.

(6) Errors in diagnosis caused delay in operation in 25 per cent of the cases and occurred in 13 per cent of those with primary tenosynovitis, and in 38 per cent of the cases of secondary tenosynovitis. The delay averaged one day in primary cases and four days in secondary cases. The accompany-

ing infection in tissues adjacent to the tendon sheath made the diagnosis more difficult in the secondary cases.

(7) The end-results were poor. They were classed in four groups based primarily on function. Over one-third of the cases were in the poorest group. Nearly two-thirds were in the lower two groups. Only 17 per cent had complete or nearly complete function. The exclusion of 15 advanced cases with tendon necrosis at operation made very little improvement in the results.

(8) Gross necrosis of the tendon occurred in 52 per cent of cases.

(9) The Streptococcus hemolyticus was present at operation in pure culture in 36 per cent of cases, the Staphylococcus in 31 per cent. Results were somewhat better in the Staphylococcus cases. Mixed infections usually did poorly.

(10) The best results were found in the thumb and the poorest in the fifth finger.

(11) Primary tenosynovitis occurred in 67 cases, or 54 per cent, and secondary tenosynovitis in 58 cases, or 46 per cent. The results in the two groups were about the same. Unless localized to a portion of the tendon sheath, however, secondary tenosynovitis gave a much poorer prognosis. Secondary tenosynovitis was more apt to have tendon necrosis. Primary infections were most frequently caused by the Streptococcus and secondary infections by the Staphylococcus.

(12) There were 13 cases of radial bursitis, eight cases of ulna bursitis, and ten cases of combined infection of both radial and ulna bursae. All but one of the combined infections spread from the radial to the ulna bursa. Most of these cases were due to the Streptococcus hemolyticus.

(13) The average duration of tenosynovitis before operation was 6.2 days. It was nearly three times as great in Group I as in Group IV.

(14) The prognosis became definitely poorer with advancing age. Tendon necrosis also became more frequent.

(15) Sterile wet dressings of saline or boric solution seemed to give better results after operation than sterile hand soaks.

(16) There was one death, a mortality of 0.8 per cent. There were three arm and eight finger amputations. Osteomyelitis occurred in 38 per cent of cases. The middle phalanx was most frequently involved. Suppurative arthritis was most frequent in the distal phalangeal joint. The Streptococcus hemolyticus was the responsible organism in most of the severe complications.

(17) There were three cases of tenosynovitis secondary to human bites on the dorsum of the fingers and hand. All showed poor functional results.

(18) Extensions to the thenar space occurred in 15 cases, to the midpalmar space in four cases, to the forearm in nine cases, and to the wrist joint in one case. Extension from the volar to the dorsal side of the hand occurred in ten cases; in six by way of the lumbricals and webs, and in four through

the phalangeal or metacarpophalangeal joints. Extension from the dorsum to the volar side occurred only in the three human bite infections.

(19) The average period from operation to complete healing was 53 days. It was twice as long in the cases with tendon necrosis as in those without.

(20) Localized tenosynovitis occurred in 19 per cent of cases. Most of these were secondary infections. The results in these cases were somewhat better than the average.

(21) In 22 per cent of cases the tendon sheath was incompletely drained. Over half of these had to be operated upon again. The results in these cases were poorer than the average.

(22) Uninfected portions of sheaths contaminated at operation did not influence the results appreciably. In doubtful cases it is wiser to incise the whole sheath.

(23) Only four cases of tenosynovitis were due to contamination of an uninfected sheath at operation. In all these cases the infection lay close to the sheath and probably would have involved it later. In doubtful cases of tenosynovitis it is much wiser to operate than to delay.

(24) Delay before operation is probably the most important cause of the poor results.

(25) Gonococcus tenosynovitis occurred in seven cases during this period. All were hematogenous. There was no tendon necrosis or other complication. The results were all unusually good.

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PROPHYLACTIC FOOT TREATMENT IN PATIENTS WITH DIABETES MELLITUS

ANALYSES OF ITS EFFECT ON THE PREVENTION OF INFECTION OF THE LOWER EXTREMITIES AND THE OPERATIVE PROGNOSIS IN A SERIES OF FIVE HUNDRED SEVENTY-SIX CASES

HAROLD BRANDALEONE, M.D., SAMUEL STANDARD, M.D., AND ELAINE P. RALLI, M.D.

NEW YORK

FROM THE DIABETIC CLINICS OF THE THIRD (NEW YORK UNIVERSITY) MEDICAL DIVISION, BELLEVUE HOSPITAL, AND THE DEPARTMENTS OF MEDICINE AND SURGERY, NEW YORK UNIVERSITY COLLEGE OF MEDICINE

THE occurrence of infections of the lower extremities in patients with diabetes mellitus is so well recognized that further reference to the subject might seem unwarranted but for the fact that these infections continue to be, frequently, the etiologic factor of diabetic gangrene. The prevention of this complication is the aim of every diabetic clinic and it is because of this that we are reporting the effect of prophylactic foot treatment on the incidence of foot infections in the Diabetic Clinic of the Third (New York University) Medical Division of Bellevue Hospital. The number of active diabetic patients attending this clinic at the present time is 576. An average of 70 patients are seen weekly. Due to the yearly increase in the number of patients attending the clinic the problem of foot infections is important, as this complication often necessitates prolonged hospitalization and financial loss to the patient. Therefore in May, 1933, a foot treatment room was established in the hope of preventing infections of the feet and for the treatment of minor infections not requiring hospitalization. No attempt was made to make oscillometric determinations, but a record was kept of the condition of the feet, including the texture of the skin, the presence of calluses, corns, abrasions, ulcers or infections and the condition of the toenails.

Set-Up of the Foot Treatment Rooms.—Two rooms are used, one for female and one for male patients. There are four chairs in each room. The personnel consists of a physician in charge of both rooms, one graduate nurse and two clinical clerks for each room. The nurses and clinical clerks are trained in the technic used in the care of the feet. Major surgical work is never done in the clinic; the treatment consists mainly of the care of infected calluses and corns, none of which requires any anesthesia. The foot rooms run concurrently with the clinic and appointments for foot treatments are made so that the patients visit the foot room approximately every six to eight weeks. If any infection is present, weekly visits are required. New patients are treated in the foot room on their first visit.

Procedure.—Instructions to new patients: Each patient is given a mimeographed sheet of instructions (Table I) consisting of the procedure for daily foot care and of Buerger's exercises. These instructions and the reason for

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such care are explained to the patient. The dangers of foot infections, the necessity for properly fitted shoes and warm stockings in cold weather are also gone over.

TABLE I

DIRECTIONS TO PATIENTS

(1) *Care of Feet*

A. The feet should be soaked in a basin of warm soapy water for five minutes every day.
B. They should be dried thoroughly with a Turkish towel. Be careful to dry in between the toes.
C. They should be massaged with a little alcohol.
D. They should be massaged with lanolin, especially the soles of the feet where there are calluses, and the heels. In this way the calluses are softened and will eventually rub off.

(2) *Foot Exercises*

A. Sitting on the edge of the bed, point the toes upward and then downward. Repeat this ten times.
B. Then make a complete circle with the foot ten times.
C. Then raise both legs to an angle of 45°. As a support for the legs, the patient may place a chair upside down on the bed. Leave them in this position for three minutes.
D. Then let them hang down over the side of the bed again for three minutes.
E. Then place them flat on the bed for three minutes. Cover with blanket.

These exercises should be repeated six times. They should be done daily, and if the feet have a tendency to coldness, they should be done twice a day.

Care in the Clinic.—The patient is seated in a chair and the feet soaked for five minutes in warm soapy water. They are then thoroughly dried and toenails cut. Corns and calluses are cared for as follows: The noninfected calluses are soaked daily and this is followed by massage with lanolin. Where there is accumulated serum under a firm plaque of callus, the plaque is dissected away to remove pressure and an alcohol and boric dressing applied. The patients are instructed to soak the feet several times daily and to apply a clean wet dressing to the area. Corns are treated in the same manner. Particular attention is given to epidermatophytosis, which is treated as follows: The feet are soaked in the usual manner. Care is taken to insure complete drying. Whitfield's ointment containing 1 per cent salicylic acid is applied. This procedure of soaking, drying, and application of ointment is done daily for one week. The ointment is then discontinued for a week. The toes are kept separated by small pieces of gauze and talcum powder is shaken in between the toes. In most cases ulceration clears up by the end of a week; if this does not occur, treatment is repeated. This routine is continued until the ulceration has disappeared.

The treatment of ingrowing toenails depends on their severity. In mild cases in which the nail is inverted the edges are merely raised with an orange stick and small pieces of cotton are inserted beneath it in order to prevent further inversion. In more severe types a triangular section of the side of the affected nail is removed. The apex of this triangle is towards the base

of the nail. This procedure leaves a space which is then packed with cotton in order to prevent the new nail from inverting as it grows out.

Results.—The two year period prior to the establishment of the foot treatment room, May, 1931, to May, 1933, will be referred to as Period I; the period following the inauguration of routine foot treatment, May, 1933, to May, 1935, as Period II. During Period I 34 clinic patients were hospitalized because of infections of the lower extremities (Table II). During

TABLE II

ANALYSES OF CLINIC PATIENTS, 1931–1935

	Period I (No Foot Room)	Period II (Foot Room)
Number of patients	338	576
Total number of visits	4853	6682
Number of patients receiving foot care	none	367
Per cent requiring hospitalization for infection of lower extremities	10 per cent	4.6 per cent

the years 1931 to 1933, 34 patients, who had never been to a diabetic clinic, were also admitted to the hospital with infections of the feet, and during the next two years 26 nonclinic patients were admitted. If we consider first the effect of prophylactic foot treatment on the clinic patients (Table III), the number of patients requiring hospitalization for infections of the lower extremities fell remarkably, *i.e.*, from 10 to 4.6 per cent in spite of a 70 per cent increase in the total census of the clinic. The effect goes further than this, as shown by the results of hospital treatment. The mortality dropped from 8.8 to 3.7 per cent and the number of patients requiring amputation from 32.4 to 25.9 per cent.

TABLE III

RESULTS ON HOSPITALIZED PATIENTS, 1931–1935

	Clinic Period I No Foot Treatment		Clinic Period II Foot Room Treatment		Nonclinic Patients	
	Number	Per Cent	Number	Per Cent	Number	Per Cent
Number hospitalized	34		27		60	
Improved	29	85.3	26	96.3	33	55
Unimproved	2	5.8	none		4	6.7
Died	3	8.8	1	3.7	23	38.4
Amputated	11	32.4	7	25.9	25	41.6
Cause of death						
Postoperative	3		0		16	
Nonoperative	0		1		7	

NOTE.—Of 367 patients treated in foot room from 1933 to 1935, only three required amputation.

The effect of proper treatment of the diabetes on the outcome of foot infections can be gathered by comparing the clinic treated patients of Group I with the nonclinic patients (Table III). In the group in which neither

the diabetes nor the feet had been treated, 41.6 per cent required amputation and 38.4 per cent of these patients died. In our clinic group prior to prophylactic foot care 32.4 per cent required amputation, and 8.8 per cent died. Obviously, control of the diabetes with a consequent improvement in the state of nutrition of the patient are important factors in improving the prognosis. Naturally, the patient attending a clinic regularly can be hospitalized before infection sets in, and this further improves the prognosis.

Obviously previous control of the diabetes improves the prognosis in a patient with infection of the feet, but if prophylactic care of the feet is carried out systematically at the same time, the prognosis is greatly improved. Care of the diabetes alone improved the prognosis 77 per cent; when prophylactic foot care was added to this, prognosis improved 90.5 per cent.

TABLE IV

CLINIC AND NONCLINIC PATIENTS

Relation of Infection to Age, Sex, Sites of Lesion and Insulin Requirement

Relation of Age to Infection				
Age Group	No. Pts.	Sites of Lesions	Sex	Insulin
10–20	0	Great toes.....33	Males.....61	Pts. requiring
20–30	2	1 with other toes	Females...60	insulin.....98
30–40	3	Small toes.....32		No insulin.....23
40–50	17	1 with great toe		
50–60	33	Foot.....24		
60–70	48	2 with other toes		
70–80	15	Plantar		
80–90	3	Callus..... 8		
		1 with great toe		
		Heel..... 6		

Several other interesting facts were brought out as a result of this study (Table IV). The major portion of infections occurred between the ages of 50 to 70. There was a definite rise in infections after 40. The large and small toes were almost equally involved, probably because these are the sites where pressure from improper shoes is likely to occur. As far as sex was concerned the patients were equally divided. If insulin can be used as a criterion of the severity of the diabetes, the severe diabetics were four times as liable to infection as the mild cases.

CONCLUSIONS

As a result of these findings it seems justifiable to include prophylactic foot treatment as a routine part of the treatment of patients attending a diabetic clinic, as has long been advocated by Joslin and his colleagues.[2, 3] This care involves the recognition of vascular inadequacies of the extremities and their dangers to the diabetic patient. For this reason we believe that such care should always be under the supervision of a physician. When

the foot treatment room was first opened in this Diabetic Clinic the patients considered the procedure time consuming and unnecessary. However, when they saw the importance that the physician attached to this treatment, and became aware of the comfort it afforded them, their attitude changed. They were stimulated to take better care of their feet at home, to do the prescribed exercises and to come into the clinic if anything developed before their next clinic appointment. Now the care is so much a matter of routine to the patients that they can be depended upon to report regularly to the foot room.

Our impression is that the most frequent cause of infection of the feet in these patients is improper shoes. This superimposed upon arteriosclerosis, which undoubtedly exists in patients of the age group most frequently involved, is too much for the resistance of a patient with diabetes mellitus.

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ADAMANTINOMA OF THE JAW*

ROBERT H. IVY, M.D., AND LAWRENCE CURTIS, M.D.
PHILADELPHIA, PA.

ADAMANTINOMA is a tumor derived from the enamel-forming cells of the dental epithelium. The term is open to some criticism because it implies something very hard, whereas calcification or enamel formation in the tumor is unknown. It has been suggested by Churchill and one of the writers that a more accurate term would be ameloblastoma, and this is approved by McFarland, but it may be difficult to obtain universal adoption of a new name when the older one is so firmly established. In 1931, McFarland and Patterson[3] published a review of 196 cases reported in the literature, and appended a very large bibliography. Since that time there have appeared several articles recording small series of cases. We believe that the series of 16 cases herewith reported is large enough to permit some conclusions.

The tumor is usually multiocular cystic in character, but frequently, especially in its earlier stages, consists largely of solid tissue. The portion of the jaw involved, usually the molar region of the mandible, but not necessarily so, is distended, containing a lobular mass within a bony cavity, which may protrude from the alveolar border or extend into the surrounding soft tissues by perforation of the cortical plates of bone. The growth contains numerous cavities filled with a viscid brownish fluid. The cystic cavities, which vary greatly in size, present a lining with papillary projections which may partly or completely fill the cavity. The septa between the cavities consist of fibrous tissue and sometimes of bone. The cysts possess a lining of flattened or cuboidal cells, and columns of epithelial cells may be found in the fibrous stroma. Columnar cells are seen, resembling the columnar cells of the enamel organ (ameloblasts), these cells surrounding spaces containing a structure having the appearance of stellate reticulum or enamel pulp. These histologic characteristics clearly indicate the derivation of the tumor from the enamel organ (Fig. 1). The epithelial cells have been known to take on invasive properties, thus resembling epithelioma, though metastases are almost unknown. In general, it may be said that the tumor is benign, with remote possibilities of malignancy. It may be found at any age.

Symptoms and Diagnosis.—A painless swelling is present, usually in the molar region of the mandible, which has slowly been increasing in size. The alveolar border of the jaw is found to be enlarged, the outer alveolar plate being more affected than the inner one. When the tumor is larger, it may have a lobulated surface with thinning of the overlying bone, and feel elastic on pressure. If an opening into a cystic cavity exists, a fluid discharge is

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CHART I

DIFFERENTIAL DATA ON EPITHELIAL TUMORS AND CYSTS OF THE DENTAL SYSTEM

Tumor	Origin	Pathologic Anatomy	Roentgen Ray	Age	Clinical Characteristics	Prognosis	Treatment
1. Adamantinoma (ameloblastoma).	Aberrant growth of epithelial cells which are prototypes of those forming inner layer of enamel organ (ameloblasts).	Cavity in bone divided into numerous compartments by fibrous or bony septa. Some of the spaces are cystic, containing fluid, others are filled with solid tissue. Epithelium is cuboid or columnar, and arranged in strands or alveoli, surrounding a stellate reticulum.	Cavity in bone divided by fine trabeculae into compartments varying in size.	Any age.	Painless expansion of bone, usually in molar region of mandible, slowly increasing in size. May be an opening into mouth from cystic cavity.	Recurrence common unless radical operation is done.	For small growths shelling out and curettement may suffice. For larger ones complete resection of portion of mandible involved.
2. Dentigerous (follicular) cyst.	Cyst lining formed by epithelium of peripheral layer of enamel organ.	Single cavity in bone. Membrane is lined with layers of squamous epithelium. Contains thin fluid and the crown of an unerupted tooth projects into the cyst from its bony wall.	Clear area of absence of bone, with well-defined margins, containing an unerupted tooth.	Any age, but particularly about time of eruption of permanent teeth.	Slowly increasing painless expansion of a part of the bone, which later may become very thin and give parchment or celluloid-like feeling. Absence of a tooth from the series in the region of the swelling is significant.	Readily cured by suitable operation.	Operation through flap of gum. Complete removal of cyst with its capsule, together with unerupted tooth.
3. Dentoperiosteal (dental root) cyst.	Abnorma growth of epithelial cell-rests normally present in dental periosteum, derived originally from outer epithelial ayer of enamel organ (paradental epithelial rests of Malassez).	Cavity in bone about apex of permanent tooth whose pulp has been devitalized. Cavity lined with multiple layers of squamous epithelium and contains fluid with cholesterol crystals.	Radiolucent area in bone with clearly defined margins in connection with apex of pulpless tooth or in part of bone from which pulpless tooth has been removed.	Adults.	Presence of pulpless tooth or history of previous removal of such a tooth. Slowly increasing painless expansion of bone. Puncture allows discharge of clear fluid or pus if secondary infection is present.	Readily cured by suitable operation.	Flap made in gum. Removal of offending tooth if present. Epithelial lining shelled out in most cases.

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seen, usually viscid and brownish. Infection may occur, the nature of the tumor being obscured by symptoms of osteomyelitis. A differential diagnosis from purely inflammatory conditions and from other tumors and cysts can usually be made by the roentgenologic appearance, which shows the growth divided by fine bony compartments. Occasionally, it is almost impossible, preoperatively, to differentiate adamantinoma from benign giant cell tumor, osteitis fibrosa cystica, sarcoma, and other conditions.

Chart I gives the data enabling one to differentiate adamantinoma from the other two common types of cysts derived from dental epithelium. Some writers[1] have attempted to show that adamantinoma may develop from a dentigerous cyst. This may be explained by the findings of Churchill,[2] who has recently called attention to the fact that the epithelial lining of a dentigerous cyst may undergo proliferation and assume a histologic picture

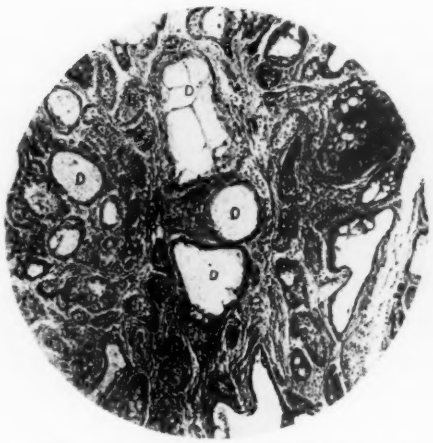

FIG. 1.—Photomicrograph taken from a section of an adamantinoma of the mandible, showing the different developmental stages of the tumor (Dr. H. R. Churchill).

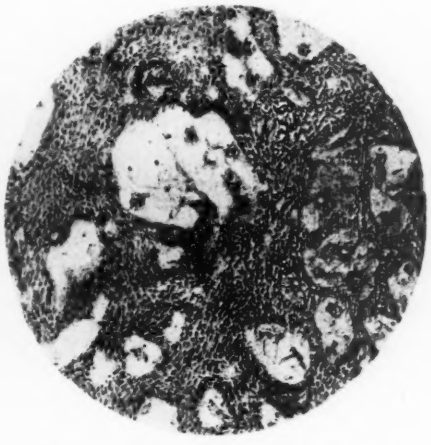

FIG. 2.—Photomicrograph taken from a section of the invading wall of a dentigerous cyst, showing general resemblance to structure of adamantinoma. However, note vascularization in spaces, and tendency of epithelium to assume cuboidal and columnar shapes (Dr. H. R. Churchill).

suggestive of adamantinoma, but has shown that there are certain definite characteristics which permit a differentiation to be made. "Proliferations from the wall of a dentigerous cyst may invade the adjoining tissue and form separate epithelial strands which enclose smaller or larger areas of connective tissue. The latter, when entirely enclosed in the proliferating epithelium, may finally simulate the contents of the follicle which characterizes the adamantinoma. The fact that thus far no vascularization has been encountered in the follicles of true adamantinomata constitutes an aid in the differentiation of these invading dentigerous cysts and adamantiomata (Fig. 2). But also, the lining of these enclavements can histologically be differentiated from the lining of the true follicles." It is quite likely, therefore, that many growths have been diagnosed adamantinoma, when they are in reality aberrant dentigerous cysts. In fact, Churchill has pointed out this difference in

some of our own cases. However, the clinical course of these aberrant dentigerous cysts very closely resembles that of adamantinoma, so that for practical purposes of treatment it is just as well, for the present, to regard them as one and the same.

Other conditions in the jaw which clinically resemble adamantinoma very closely, and thus present difficulties in differential diagnosis are: (1) Localized osteitis fibrosa; (2) benign giant cell tumor; (3) osteogenic sarcoma, and (4) metastatic growths.

In typical cases all of these are characterized by painless, slowly expanding swelling of the bone, with thinning of the cortical plate and later breaking through this plate and bulging into the soft tissues.

(1) Localized Osteitis Fibrosa.—The jaws, especially the mandible, may be the seat of a localized osteitis fibrosa, unaccompanied by any demonstrable evidences of parathyroid overactivity. Even by roentgenologic examination it is frequently difficult to differentiate from adamantinoma, since the roentgenogram shows a moth-eaten or honeycombed condition of the bone, with well-defined margins, and areas with larger spaces. The presence of several areas of this kind in the same bone would make the diagnosis of osteitis fibrosa more probable.

(2) Benign Giant Cell Tumor.—It is probable that this is a stage of osteitis fibrosa. When starting in the interior of the bone, usually the mandible, the tumor causes an expansion of the outer and inner plates. In the presence of a slowly enlarging, painless, expansile swelling of the bone, the possibility of a benign giant cell tumor should be considered. If the cortical plate of bone becomes perforated by the tumor, the mass seen in the mouth will have a typical purplish color. Otherwise, absolute diagnosis may not be possible before operation. On incision, the benign giant cell tumor has a characteristic dark red color, as contrasted with other tumors whose color is usually a pale gray.

(3) Osteogenic Sarcoma may clinically resemble adamantinoma, but usually develops more rapidly, and the outlines of the growth as seen roentgenologically are usually less well defined.

(4). Metastatic or Secondary Growths may occur in the jaw bones, especially the mandible, just as in other bones, from malignant tumors of other tissues of the body. The primary growth is usually carcinoma, and may occur in the breast, thyroid, intestine or other organs. These secondary growths in the jaws cause swellings similar clinically, and sometimes roentgenologically, to those produced by adamantinoma and other tumors mentioned. They may be suspected to be metastases in patients with a history of a malignant tumor elsewhere. On the other hand, recognition of the jaw metastasis may lead to search for a hitherto unsuspected primary growth, as in a recent case of malignant papilloma of the rectum. We have also seen a jaw metastasis from a thyroid tumor, undiagnosed clinically.

Of 16 personal cases of adamantinoma, 15 involved the mandible and one

the maxilla. Seven occurred in males and nine in females. Eleven were white persons and five were Negroes.

Treatment.—It is very important that every particle of the abnormal epithelium be removed, as otherwise recurrence will surely follow. In early cases, when the tumor is small and surrounded by well-defined bony walls, it is sometimes possible to obtain a cure by enucleation and curettement, without complete resection and solution of continuity of the mandible, but even in these cases, recurrence is not infrequent. Pichler[4] calls attention to the fact that resection in continuity of the lower jaw is a serious and mutilating operation, and only justifiable as a last resort in the treatment of a benign tumor such as adamantinoma. He has obtained good results by enucleation and curettement, followed by packing, and, five to seven days later, the direct implantation of radium into the bone cavity. On the other hand, Rosenthal,[5] Simmons[6] and others advocate complete resection in all cases. In our experience, while conservative treatment has occasionally been successful, several cases treated by enucleation and curettement have suffered a recurrence and have eventually been cured by complete resection. There is no doubt that, when the tumor is large, with irregular extensions into the surrounding bone or perforation of the cortical plates into the soft tissues, complete resection should be the initial treatment. Of 15 patients in whom the mandible was involved, three are believed to be well after conservative enucleation, repeated several times in one case. Two patients are apparently well after a second conservative enucleation followed by implantation of radium. In five cases, complete resection with loss of continuity of the mandible was the initial treatment, with complete cure. Five cases, recurring after conservative operations, have finally come to radical resection, with apparent cure. In several cases, three to six months after resection of the tumor, the continuity of the mandible was restored by a bone graft from the crest of the ilium.

Case 1.—L. T., male, age 43, bank clerk. First seen May 15, 1933. Five years ago had an operation for unerupted mandibular third molar and what was diagnosed as a dentigerous cyst. About six months ago first began to notice a painless swelling of the gum in the region of the left angle of the mandible, gradually becoming larger, until it finally became noticeable externally.

Examination showed a smooth, hard enlargement of the region of the left angle and ascending ramus of the mandible, visible externally. In the mouth there was a bulging of the gum due to expansion of the bone in the region formerly occupied by the second and third molars and extending backward into the ramus. There was practically no interference with the movement of the lower jaw.

Roentgenologic examination showed a multilocular cystic condition involving the left body of the mandible from just behind the first molar tooth and extending posteriorly to involve most of the ascending ramus (Fig. 3). Clinical Diagnosis: Adamantinoma.

Operation May 19, 1933, at Graduate Hospital under avertin-gas anesthesia. Preliminary ligation of left external carotid artery through transverse incision two fingers-breadth beneath lower border of mandible. Another incision was made along the lower border of the mandible from angle to premolar region, and the soft tissue attachments

were dissected free from the bone and the tumor. The bone was sectioned with a Gigli saw just posterior to the first molar and disarticulated at the glenoid fossa. The open-

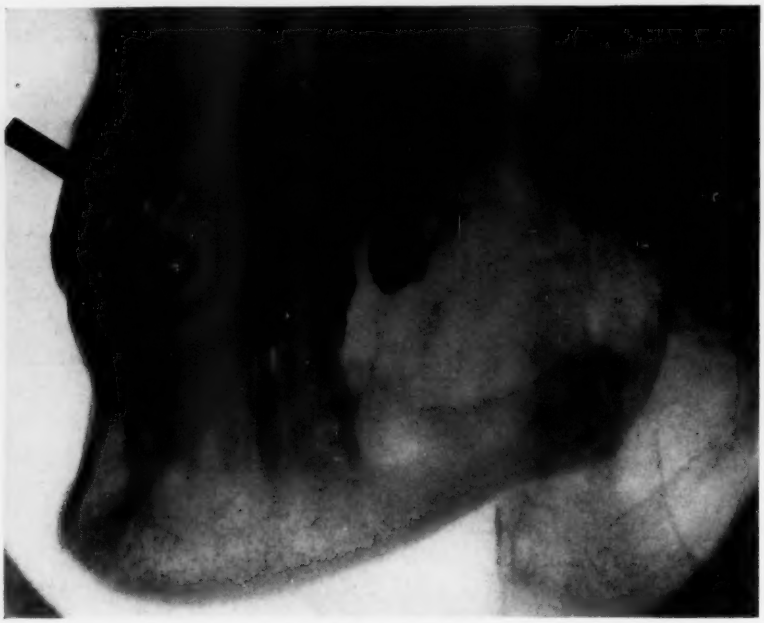

FIG. 3.—(Case 1.) Roentgenogram showing multilocular cystic adamantinoma of body and ascending ramus of left mandible.

ing made through the oral mucous membrane was closed with catgut sutures, and the cavity left by removal of bone and tumor was packed with gauze. The external wound was partially closed in layers, but sufficient opening left for later removal of the gauze.

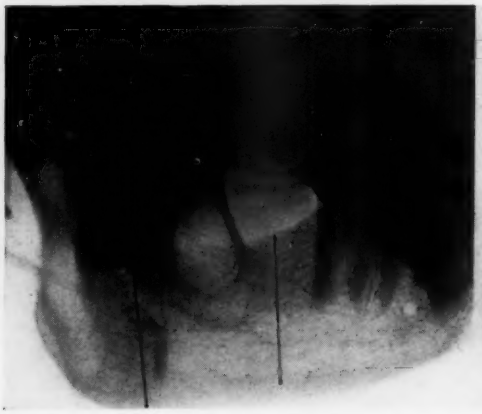

FIG. 4.—(Case 2.) Roentgenogram showing unilocular cavity in mandible due to adamantinoma (Doctors Pancoast and Pendergrass). The tissue between the vertical lines was resected.

FIG. 5.—(Case 2.) Specimen removed at operation.

The upper and lower teeth were wired together in occlusion to preserve their relationship as far as possible. This procedure also helps to keep the airway free by preventing collapse of the lower jaw and tongue.

During the next few days the gauze packing was gradually withdrawn through the external incision, which, after some drainage of pus and saliva, closed completely in about three weeks. The wires were removed from the teeth after eight weeks. At first, the remaining part of the mandible tended to drift toward the left, but, with use, the patient gained more power and was eventually able to maintain the correct occlusion.

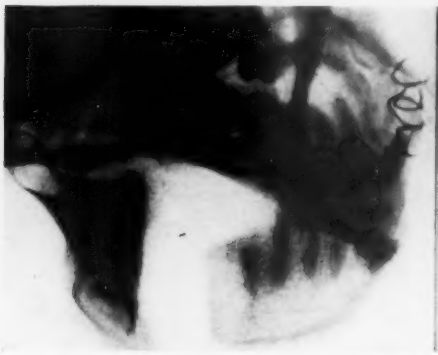

FIG. 6.—(Case 2.) Roentgenogram made after resection of involved portion of mandible (Dr. Carl Kornblum).

FIG. 7.—(Case 2.) Roentgenogram showing bone graft from crest of ilium to restore continuity of mandible (Dr. Carl Kornblum).

It was considered unnecessary to attempt either surgical or prosthetic restoration of the missing bone.

Pathologic examination, by Dr. E. A. Case, of the tissue removed at operation showed typical adamantinoma. The patient was living and well two years after operation.

Case 2.—Female, single, age 22. Was first seen in January, 1934, at the University Hospital, where she had been admitted on account of a swelling in the mouth posterior to the lower right third molar region. The lower right second and third molars had been removed about a year previously, on account of soreness and gradual loosening. Since the extraction the third molar socket had never completely healed, and a painless

FIG. 8.—(Case 2.) Photograph of patient after operation, showing little or no disfigurement.

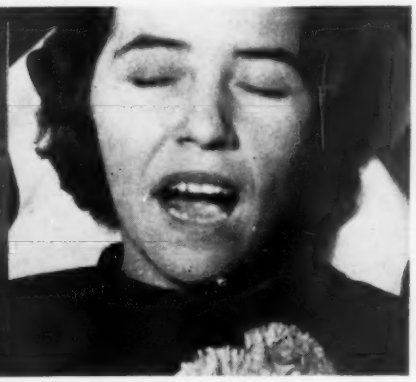

FIG. 9.—(Case 2.) Showing normal opening of mouth after operation.

swelling, slowly increasing in size, remained on the gum in this region. Examination revealed a smooth soft bulging of the gum over the lower right third molar region, evidently connected with the bone. Roentgenologic examination (Fig. 4) showed a smooth, oval cavity with well-defined margins in the angle formed by the ascending ramus of the mandible and the alveolar process, about 2 cm. in diameter. A tentative diagnosis of dental cyst was made, and the cavity was opened intra-orally and its con-

tents curetted out by Dr. Thomas Cook. The pathologist reported the tissue to be adamantinoma. The patient was discharged from the hospital and instructed to return for reexamination in three months. On May 30, 1923, with the intraoral swelling still present, a roentgenologic examination revealed a persistence of the cavity in the bone, with no diminution in size. Radical operation was then advised.

Operation.—June 7, 1934, at the Graduate Hospital. Avertin-gas anesthesia. Preliminary ligation of right external carotid artery through transverse incision. An incision was then made at the right lower border of the mandible, curving back slightly around the angle and extending anterior to the facial artery notch. The outer and inner surfaces of the ascending ramus were denuded of soft tissues. The bone was divided anteriorly through the third molar region with a Gigli saw, without entering the mouth, and posteriorly a vertical section was made from the mandibular (sigmoid)

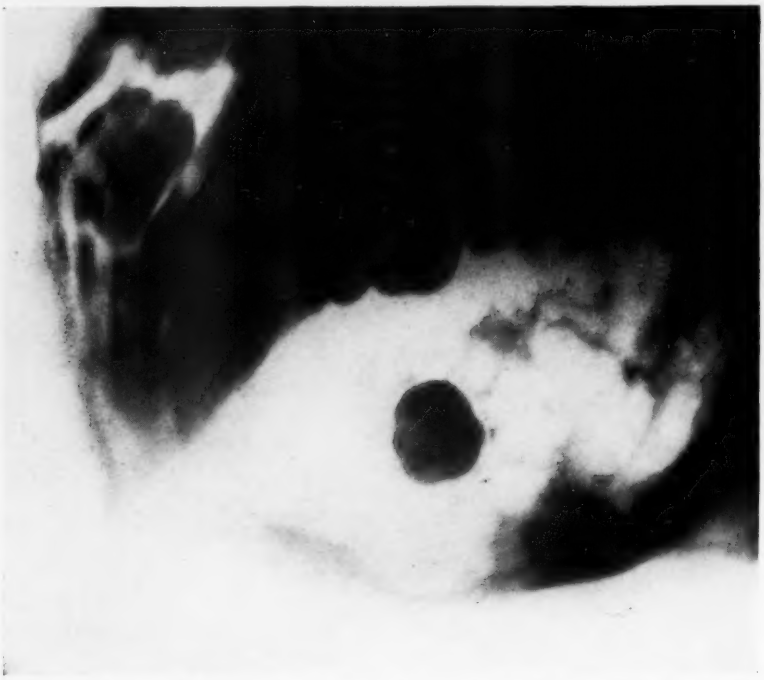

FIG. 10.—(Case 3.) Large multilocular cystic adamantinoma of left mandible (Dr. L. M. Ennis).

notch above to about 1.5 cm. in front of the angle below. The intervening portion of bone was removed, including the coronoid process, after dividing the soft tissue attachments. On the inner aspect of this piece of bone an indurated mass of pathologic tissue extended into the internal pterygoid muscle, peritonsillar and soft palate regions. In removing it a small opening was made through the mucous membrane of the mouth. In the portion of bone removed was a cavity containing pathologic soft tissue. There was a large perforation in the inner aspect of the bone and a smaller one externally (Fig. 5). Immediately after the operation the patient's jaws were fixed by wiring the upper and lower teeth in occlusion. After ten days she was discharged from the hospital with the fixation maintained on the teeth. The external wounds healed uneventfully. Pathologic examination of the tissue confirmed the previous diagnosis of adamantinoma.

The patient returned for examination in September, 1934. Teeth were found fixed in good occlusion. Incisions healed, no evidence of return of the growth or presence

of infection. Roentgenograms showed a gap in the bone corresponding to the portion removed at previous operation (Fig. 6). Under ether anesthesia the scar beneath the right lower border and angle of the mandible was opened, the bone ends were exposed and freshened, and the gap between them was bridged by a graft from the crest of the right ilium, 3 cm. long, fixed in place by fine brass wires passed through holes drilled in the bone ends and in the graft. The overlying soft tissues were closed without drainage. Healing was uneventful. The patient left the hospital 12 days later, without disability, the teeth being still wired together (Fig. 7).

Patient returned for examination in October, 1935. There were no signs of recurrence of the tumor, solid union of the jaw had occurred, with normal masticatory function, and there was no noticeable external deformity (Figs. 8 and 9).

Case 3.—J. L. Colored, age 40, laborer. First seen March 21, 1934. Six years ago he began to have swelling of the left side of the lower jaw. This had gradually increased in size. It was painless until recently, when the gum became sore from the upper teeth biting into it. He has had the molar teeth removed on that side at different times, and on one occasion the swelling was opened by an incision in the mouth.

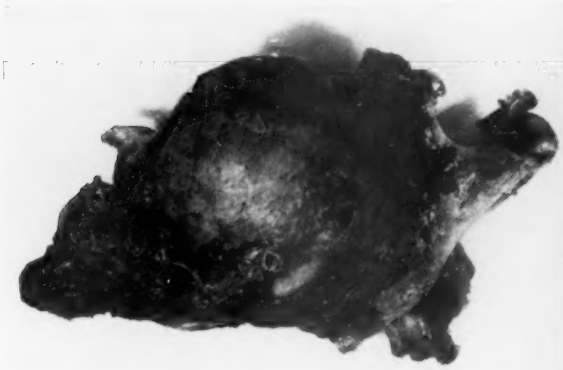

FIG. 11.—(Case 3.) Specimen removed at operation, extending from left condyle to premolar region.

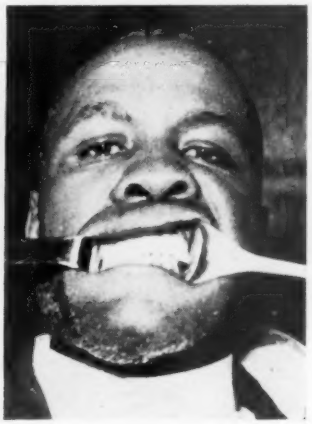

FIG. 12.—(Case 3.) Photograph of patient after operation, showing ability to occlude teeth.

Examination showed a very large swelling over the left side of the mandible from the mental foramen region back. This was fairly hard, clearly involving the bone, with the soft tissues stretched over it, but it yielded to pressure in places. No tenderness on palpation through the skin. Inspection of the mouth showed a nodular bulging of the mucous membrane over the left side of the lower jaw, and this was inflamed in places where the upper teeth bit into it. There was a small opening in the mouth, through which fluid escaped.

Roentgenologic examination showed enlargement of the entire left side of the mandible, from the mental foramen region extending well up into the ascending ramus. The cortical portion of the bone was very thin in places and the entire area showed spaces of various sizes divided by bony septa. In the center was a mass representing an unerupted molar tooth (Fig. 10). Clinical Diagnosis: Adamantinoma.

Operation.—March 23, 1934. Graduate Hospital. Ether anesthesia. Ligation of left external carotid artery. Resection of left side of mandible from mental foramen to joint (Fig. 11). Upper and lower teeth wired together with ligatures, to maintain relationship of remaining lower teeth to those of upper jaw. The wires were removed on March 31, and it was found that he had sufficient control to bring his upper and lower teeth into occlusion (Fig. 12). The wound, which communicated with the mouth, healed

after about four weeks. Pathologic examination, of the tissue removed at operation, confirmed the clinical diagnosis of adamantinoma.

SUMMARY.—Of 16 cases of adamantinoma 15 involved the mandible and one the maxilla. Seven were in males and nine in females. Eleven were white and five Negroes. Four were treated by conservative enucleation; two by conservative enucleation followed by radium; five by primary complete resection with loss of continuity of the mandible; five by secondary complete resection after recurrence following conservative enucleation.

CONCLUSION

From these results, it would seem that primary complete resection is the method of choice in the great majority of cases.

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UNUNITED FRACTURES OF THE SHAFT OF THE HUMERUS

WILLIS C. CAMPBELL, M.D.
MEMPHIS, TENN.

REPORTS of end-results in any large series of ununited fractures of the humerus are so exceedingly rare that an analysis of 50 cases may be of interest.

Delayed union and nonunion occur in a higher percentage of fractures of the shaft of the humerus than in any other long bone. This is due to two factors: first, the utter impossibility of complete immobilization by any type of external apparatus; second, the difficulty in maintaining complete coaptation of the fragments and preventing a definite space between them which may exist despite a good anatomic alignment. Engagement and locking of the fragments in the humerus is rarely as secure as in the femur because the soft tissues are more relaxed. In our series of 226 ununited fractures of the long bones which were treated by massive onlay graft to be described later, there were 53 in the tibia, 32 in the femur, 52 in the humerus and 89 in the forearm (considering each bone as a separate surgical equation). Nonunion is observed more frequently in the tibia and forearm but fractures of the shaft of the humerus are of much less frequent occurrence, which accounts for the relatively small number but higher percentage of nonunion. Of 4,000 fresh fractures of the shaft of the long bones the distribution was as follows: leg, 1,066; femur, 758; forearm, 1,883; humerus, 293.

When nonunion occurs in the shaft of the humerus, failure to secure union is more frequent than in any other long bone, which is quite evident from the record of many operative attempts without success, often by well trained and able surgeons. Sever has recently reported a series of his own failures and calls attention to the fact that the procedures commonly employed are inadequate. He advises methods that give more accurate and definite fixation.

A fracture should not be designated as ununited until it has reached a definite status in the local reaction, so that union is impossible or very improbable. In the humerus, I believe such a state is reached somewhat earlier than in the other long bones. In a very high percentage of fractures of the humerus properly treated, union may be solid by the end of six weeks. In a smaller number there will be delayed or partial union at this time, when further immobilization will usually induce consolidation. If there is no evidence of union at eight weeks, as determined mainly by physical examination, since roentgenograms rarely give material aid as to the degree of union at this time, union can often be obtained by prolonged fixation, but in many a permanent status of nonunion results; therefore, it is often debatable whether

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it would not be better to induce union by more definite and certain methods than to submit the patient to the probability of prolonged treatment.

The causes of nonunion may be classified as constitutional and local. The constitutional causes are: (1) Constitutional diseases; (2) metabolic and endocrine imbalance; (3) diet; (4) multiple fractures; and (5) congenital abnormalities of the bone structures. Syphilis is frequently given as the cause of nonunion, but I have rarely found this affection to be the etiologic factor even in fractures in the parasyphilitic stage, or in any other systemic affection. The imbalance of the calcium-phosphorus product has been considered as a factor in nonunion. Undoubtedly the hyperactivity of the parathyroid gland, the hormone of which apparently controls calcium balance in the bone and other tissues, is the causative factor in osteitis fibrosa cystica. In this affection the calcium is absorbed from the bone with an increased calcium of the blood. In rickets the amount of calcium is decreased in the bone, but in neither of these conditions is osseous union delayed or prevented. Routinely, the blood calcium and phosphorus were determined in possibly 25 cases of ununited fractures, and the calcium-phosphorus product was normal in all. Henderson of the Mayo Clinic, and Kellogg Speed of Chicago report the same experience. Undoubtedly, after any fracture or major traumatic lesion, all agree that the patient should be placed in the best physical condition by the eradication of the foci of infection, treatment of such conditions as syphilis if present, and administration of adequate diet, *etc.* Diet is frequently adjusted to induce callus formation; also various drugs are administered, such as calcium and viosterol. I have observed many ununited fractures in which such measures had been employed without apparent benefit. However, a well balanced diet, which can be assimilated by the patient, is conducive to any healing process. In multiple fractures union progresses satisfactorily in several, but the process of repair is often delayed or fails in one or more. In 1923, I called attention to multiple fractures as a causative agent of delayed union or nonunion, for which there is sufficient evidence to support this clinical observation. Just how multiple fractures delay or prevent union is merely speculative, but it is probably due to a demand of bone production in excess of nature's ability to supply. This condition is the only one in which there is definite clinical evidence of a constitutional factor as a cause of nonunion. Nonunion very rarely may be observed in those with congenital deficiency in the quality of bone as evidenced by condensation. Possibly this may be a mild Albers-Schönberg disease or congenital abnormality. It is possible that endocrine imbalance and other constitutional factors may affect the local process of bone repair sufficiently to be the deciding element between delayed union and nonunion; therefore, it should be given due consideration.

The local causes are any factors which may impair the delicate process of repair, and I am certain, with exceedingly rare exceptions, they are the etiologic agent. In 1932, I analyzed 104 ununited fractures of the long bones, in which solid osseous union was induced in 92 per cent. The failure in the

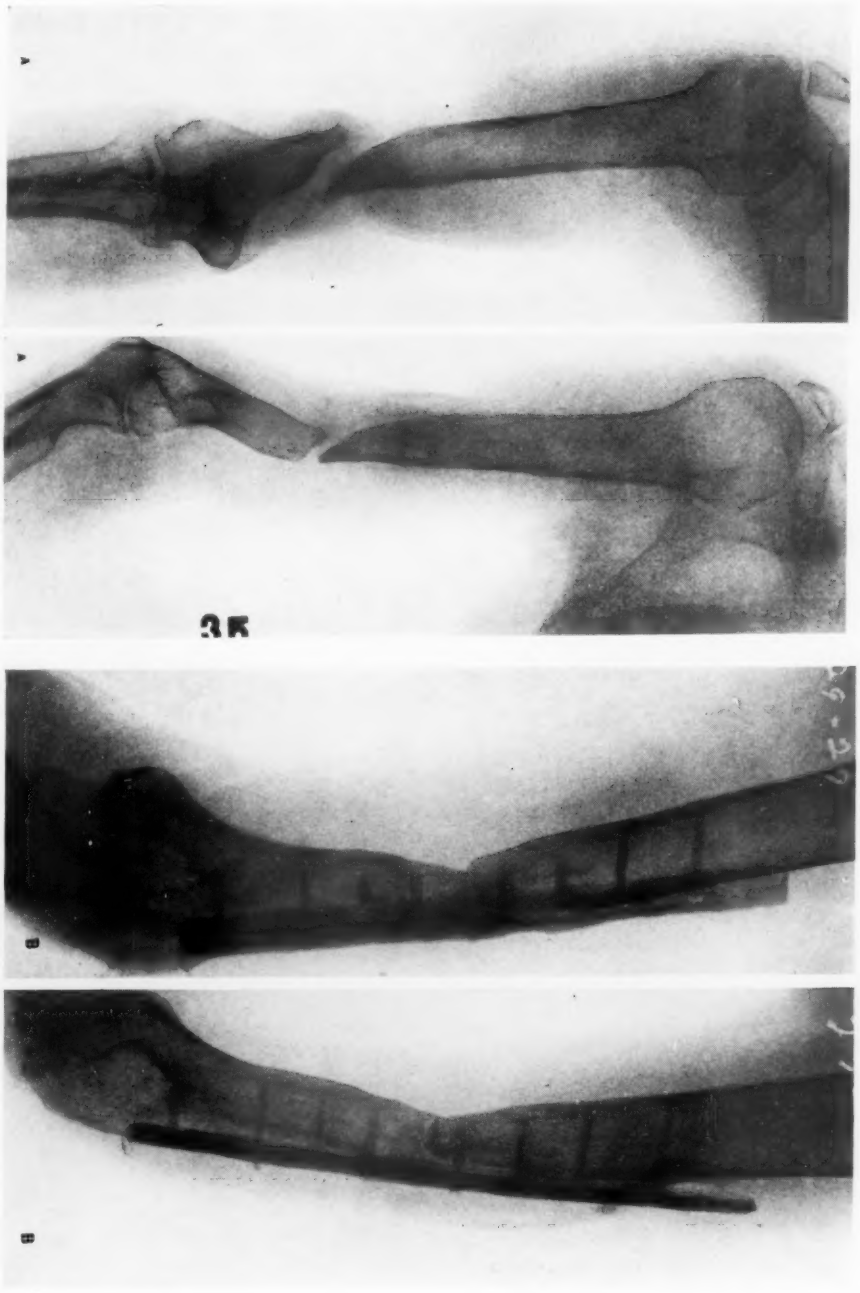

FIG. 1.—Ununited fracture of the lower third of the humerus in a patient age 52, with marked atrophy of disuse as evidenced by almost complete loss of the cortex. Note conical shape of the ends of the fragments. (B) Solid union 14 months after onlay bone graft.

remaining 8 per cent was due to definite local causes. As stated in former contributions, there has been a vast increase in the number of ununited fractures that cannot be entirely accounted for by the increase in the number of fractures; this is due to several local causes: *i.e.*, (1) More severe trauma with greater injury to the surrounding soft parts; (2) a greater number of compound fractures in which union is often delayed; (3) repeated forcible

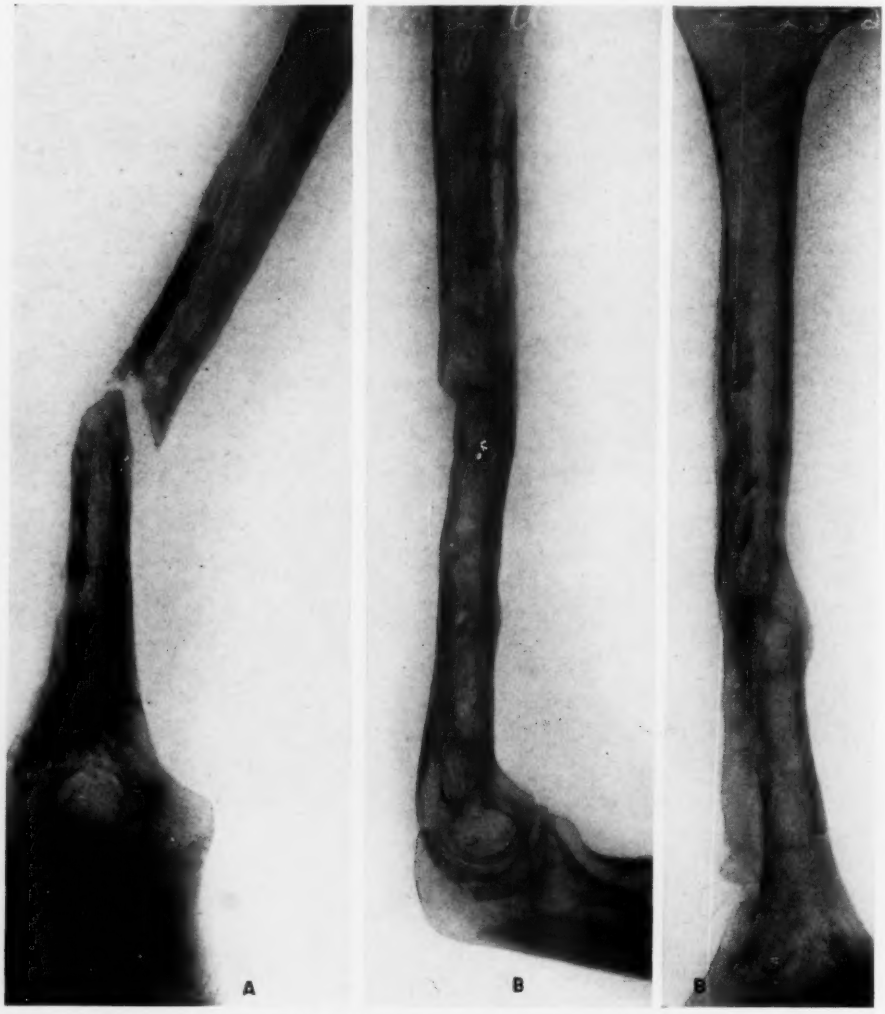

FIG. 2.—(A) Extensive osteoporosis with nonunion which shows a definite loss of lime salts, quite a different appearance from atrophy of disuse. (B) Solid union six months after operation.

attempts to secure manual reduction; (4) operative measures always impair union but frequently prevent union when employed without due regard to tissue conservation; (5) excessive traction by the improper use of the more modern methods of skeletal traction; (6) interposition of tissue and malposition; (7) sclerosis of bone following an old healed pathologic process, as

in osteomyelitis; (8) fixation by foreign bodies, such as Lane plates; and (9) inadequate immobilization.

In order to appreciate the rationale of these local causative agents a brief consideration of the delicate process of repair will be discussed. There are two theories of bone repair, the cellular and the physiochemic, but from a

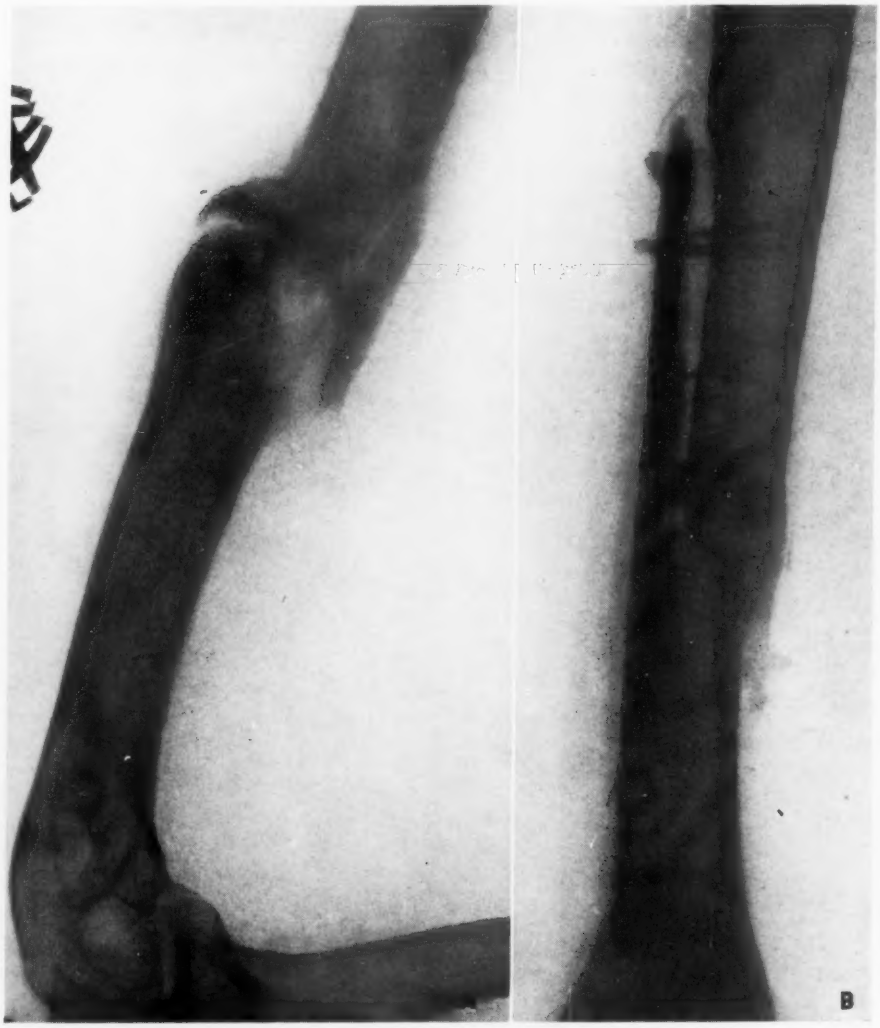

FIG. 3.—(A) Typical pseudo-arthrosis seven months after fracture with concavity on the upper fragment. (B) Solid union three months after operation with slight separation of the graft in the upper fragment.

practical point of view it makes no difference which of these one may adopt. There are three essential factors involved in osteogenesis, namely: (1) the formation of a coagulum between the fracture surfaces—the so called clot in which there is a state of stasis or aseptic necrosis; (2) an adjacent adequate supply of calcium from the fragments; and (3) surrounding the area of

stasis with free calcium supply there must be an excessive blood supply, induced by the stimulus of injury. A combination of these three factors is conducive and essential to the formation of the delicate process of repair. Osteogenesis, or bone repair, is comparable to that of fibrous tissue. It involves a complicated embryologic evolutionary process, in which may be formed various types of tissue, as preosseous, hyaline, osteoid, cartilage and true bone. The chief difference between the formation of granulation tissue

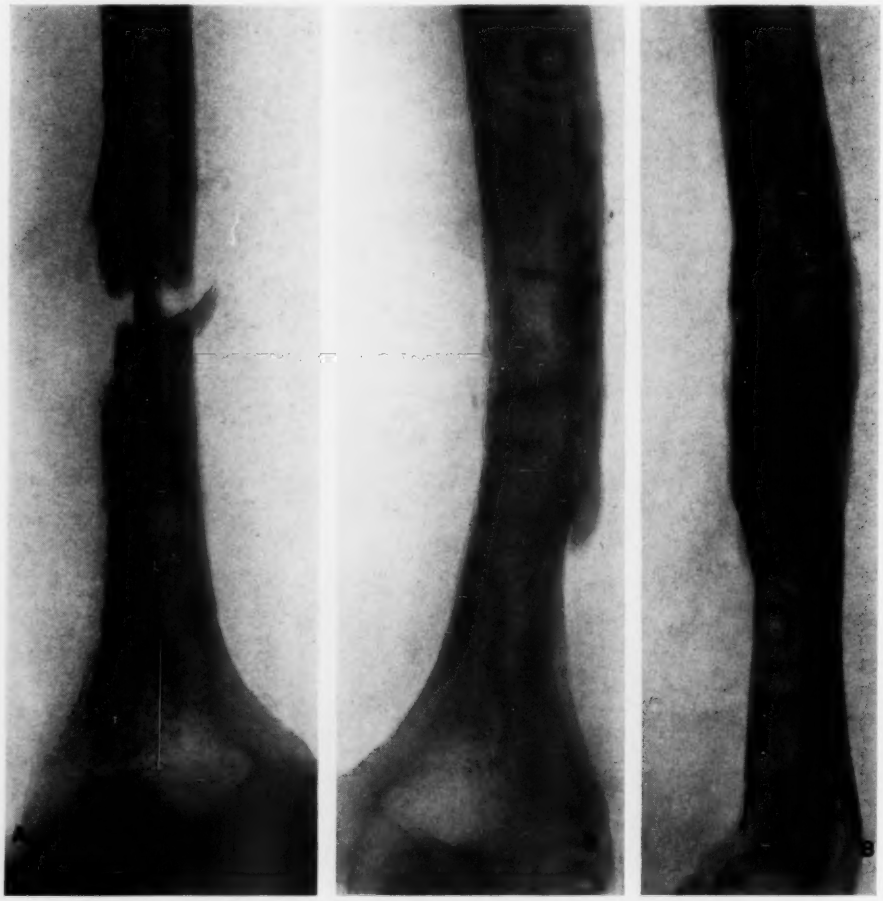

FIG. 4.—(A) Inefficient intramedullary graft with nonunion. (B) Solid union nine months after operation.

and bone is the infiltration of calcium. Bone is, of course, a connective tissue and any interference with repair may easily induce the substitution of dense adult fibrous tissue.

In the process of bone repair there are two factors of importance: osteogenesis, and osteolysis and osteoclasis—or bone production and bone dissolution, respectively—which must be well balanced to form true bone. Osteolysis is the absorption of the products of osteogenesis by some chemical agent in the tissue fluids. Osteoclasis is the destruction of bone by the giant cell

osteoclasts, which become active and increase in number after irritation or inflammation. If for any reason bone dissolution is impaired, there will be excessive callus but of low grade quality. If osteoclasis or osteolysis is increased there will be more or less dissolution of callus, if formed, or the prevention of the formation of callus. A fracture may appear to be solidly united, clinically, but after a few days undergo complete dissolution and finally reach a state of hopeless nonunion. If there is excessive local trauma

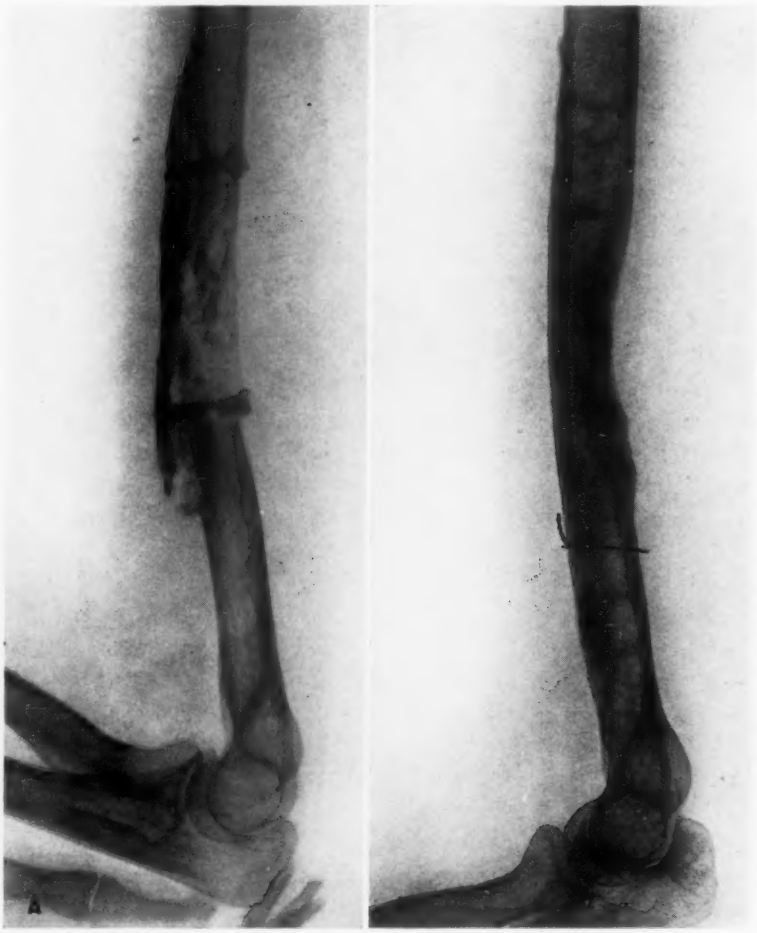

FIG. 5.—(A) Inefficient attempt to apply onlay graft with screws, resulting in nonunion and extensive osteoporosis. (B) Solid union two years after bone graft. Extensive osteoporosis necessitated use of one wire loop.

from repeated attempts to reduce the fracture, the coagulum with new embryonic cells and fibrils of repair may be extruded, or the surrounding circulation, which passes from the soft tissues through the periosteum, may be severed. The mere incision into a fracture delays union to some extent, as can be proven by a comparison of the time of consolidation between closed and open reductions. If the periosteum and soft parts are stripped from both

fragments, delay is increased and nonunion often induced. The coagulum is always lost in open operation. If the circulation is also obliterated, two of the prime factors in osteogenesis have been destroyed. Excessive skeletal traction not only may, but often does, delay union or cause nonunion by mechanically impairing the local process, as it is obviously more difficult for nature to bridge a definite space. Interposition of tissue may act in the same manner. Close approximation of fragments is conducive to union.

Methods commonly employed in the treatment of nonunion of the humerus may be enumerated as follows: (1) The denuding of osseous surfaces and approximating with absorbable or nonabsorbable suture, as wire; (2) steel plate; (3) plastic step-up or dovetailed wedging of the bone with or without suture and pegs; (4) drilling of the fragments; and (5) various types of inefficient bone grafts, as chip graft, Delagénierè graft, pegs and intramedullary grafts. This is the type of operation most frequently observed in the history of about 50 per cent of ununited fractures, and undoubtedly in many cases is the actual causative agent of continued nonunion. Union is induced in some instances despite such measures, but the question is not what nature will occasionally accomplish but by what means osseous fusion can be obtained in the highest percentage of cases. In merely delayed union, fusion can be secured by simple drilling of the fragments, or at times by other methods of local irritation, but in true nonunion such methods as above described should not only be discarded but not tolerated, as the percentage of failures is entirely too high.

The inlay method of bone graft is far superior to those above mentioned, but has the disadvantage of removing a considerable portion of the circumference of both fragments from which union is to be secured, and also, in my experience, internal fixation cannot be obtained. A similar method employed by Gill of Philadelphia and Sherman of Pittsburgh secures excellent fixation with the use of large sliding grafts and steel screws. The disadvantages are the removal of large grafts from the fragments and the employment of foreign bodies.

In 1921, after average success in the treatment of ununited fractures, I came to the conclusion that there might be an improvement in the end-results by a method which would permit absolute fixation and at the same time promote osteogenesis. I had previously employed massive intramedullary grafts, inlay and sliding grafts, which are far more efficient than methods above described, but after these procedures motion at the fracture site could always be detected. In consequence, I adopted the following operative technic in ununited fracture of the humerus and other long bones, which has not been changed since first devised.[1]

Operative Technic.—An ample incision is made on the anterolateral aspect of the arm about eight inches long. Routine dissection is made through the brachialis anticus and the biceps. The site of the fracture is exposed just beneath the brachialis anticus where possible, but when this muscle is unduly large the outer fibers are severed. All intervening scar and fibrous

FIG. 6.—(A) Nonunion of a long spiral fracture (which rarely occurs). (B) Solid union six months after operation. Fragments transfixed with autogenous bone nails. No graft necessary.

FIG. 7.—Notice in this and other cases increased dimension and strength as obtained by the onlay method.

FIG. 8.—Failure to obtain union due to technical error. Note separation of ends of fragments.

tissue is removed, the fragments are pared with a chisel or motor saw, and each medulla is reamed out until the normal relationship has been restored. An incision is made through the periosteum of each fragment for several inches, depending on the location of the fracture. The periosteum is stripped from one-half to three-fourths of an inch from the circumference, leaving the soft parts, from which the circulation is derived, attached as much as possible. With a chisel "shavings" are removed from the circumference until there is a continuous flat surface, for three or four inches when possible, on each fragment. A broad, flat, massive graft is taken from the opposite tibia, which should be of sufficient length, breadth and dimension to secure firm fixation. With the motor saw the graft is split longitudinally

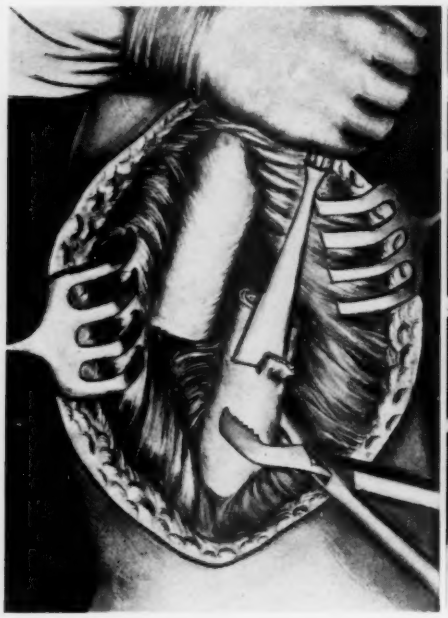

FIG. 9.—"Shavings" are removed from the circumference until there is a continuous flat surface for three to four inches on each fragment.

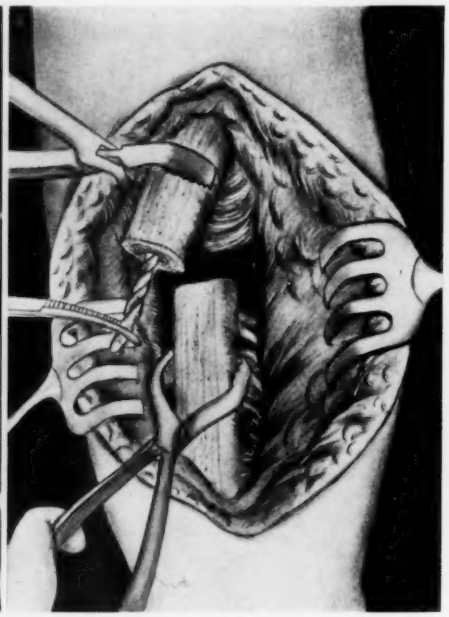

FIG. 10.—Each medulla is reamed out.

through the edge or small diameter into two parts, a strong outer plate consisting of dense bone or cortex, and an inner, the endosteum. A strip of endosteum is placed within the medulla, bridging the site of the fracture as reduction is made, normal marrow tissue rich in osteoblasts, being thus restored. From the outer plate, or as a separate graft, a strip of dense bone is taken, from which six or eight autogenous bone nails are made of appropriate size. This is accomplished by the aid of a rotary file attached to the motor saw and a metal gauge to measure dimensions. The strong outer plate is held to the flat surface of the bone passing across the site of the fracture. Three or four drill holes are made through the graft, into which the autogenous nails are driven. The remainder of the endosteum is broken into small particles and placed with the "shavings" about the site of the fracture.

Spongy bone is always available from the upper extremity of the tibia and can be obtained by a sharp bone curet. About six pieces are removed in this manner and placed around the area of the fracture. Spongy bone is more proliferative than any other type of graft, being 100 per cent successful in an operation which I devised for a type of paralytic foot. The transplantation of endosteum to the medulla and cavernous bone about the fracture is an excellent method of promoting osteogenesis. By this operative procedure solid fixation is attained at the fracture site; when the operation is complete, no motion is apparent. In ununited long oblique fractures of the humerus, which are rare, the onlay technic is unnecessary, as complete fixation can be obtained by transfixation of the fragments with autogenous bone nails.

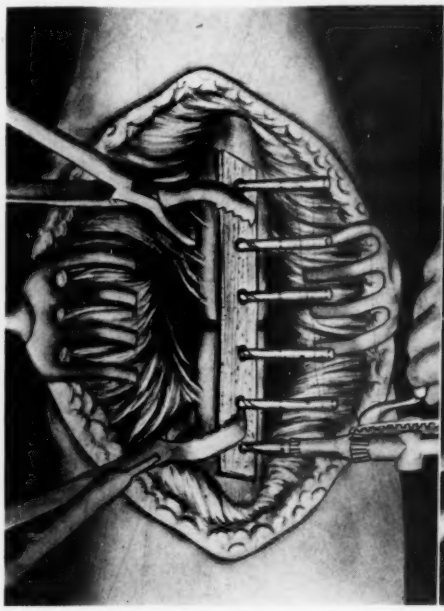

FIG. 11.—Graft consisting of dense bone or cortex with drills in place.

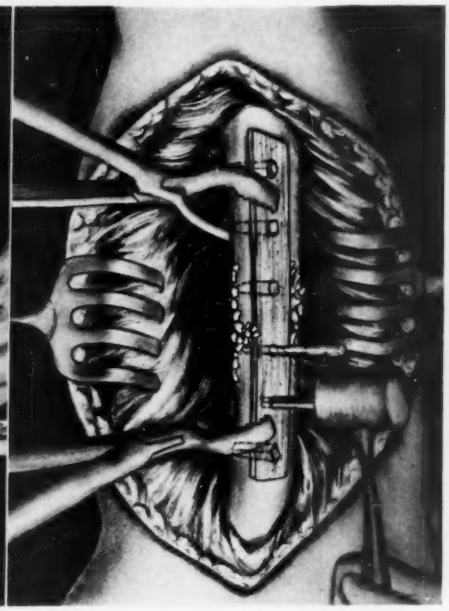

FIG. 12.—Autogenous bone nails of appropriate size inserted into drill holes.

The principles of this method are the same as those of M. S. Henderson from which the technic was devised, but differ in that the cortex is not removed from the fragments; autogenous nails are used and not beef bone screws; cavernous and endosteal bone is used to promote osteogenesis.

After the operation is completed a plaster of paris encasement is applied from the lower margin of the ribs over both shoulders down to the knuckles on the affected side. In an obese patient the cast begins below the crests of the ilium. In those with normal bone structure a special traction humerus splint may be sufficient while the patient is confined to bed, but a plaster cast is employed when ambulation is allowed. The patient is permitted to walk at the end of three weeks. At the end of eight to ten weeks the cast is removed and a leather corset similar to the cast is applied with a joint at the elbow to permit early motion. The site of the fracture remained solid after the

operation in practically every instance which terminated successfully, not the slightest motion being detected at the end of eight weeks or thereafter. However, protection of some type should be used for four to six months, commensurate with the healing of the individual case. Active motion may be employed at the end of three months or earlier. One case, in which the same procedure was employed in both bones of the forearm, left the hospital without permission within 24 hours after operation. After a few weeks he discarded all apparatus and the final result was solid union and perfect function. However, the process of bone repair which is decreased in all fractures with nonunion must be carefully guarded until there is complete consolidation. If the already deficient process is impaired from undue strain, there may be a stimulation of the process of bone resorption which causes complete dissolution and a return to the former state of nonunion. Also from slight injury the graft may be fractured, which likewise defeats the mechanical purpose of complete fixation.

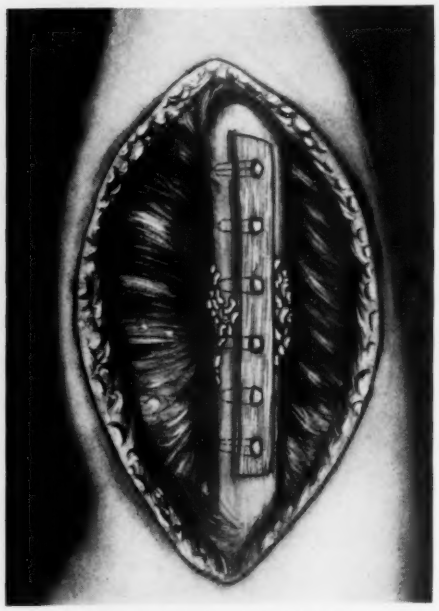

FIG. 13.—Bone graft completed. Note small particles of endosteum placed in and adjacent to the fracture site.

The bone graft must not be applied under tension or disintegration will occur with a break in the continuity of the graft. Undoubtedly this is a factor in many of those cases in which there is a fracture of the graft at the original fracture site. I have observed repeatedly such behavior when a graft has been used for conditions other than ununited fractures; for example, in bone grafts of the spine, if the transplant is placed under tension to conform to the kyphos or scoliosis, disintegration usually occurs with separation at the point of greatest stress. Also, a graft may be placed in the spine without tension, but after an increase in the destructive process there may be a gradual increase of the kyphos. In such instances, there will be disintegration at the point of greatest stress, unless there has been sufficient proliferation of the graft itself.

When there has been prolonged drainage from a mild infection, aseptic necrosis or definite disintegration of the graft occurs, followed by substitution. In those in which there is primary union, the graft shows no disintegration but apparently increases in size and becomes a part of the parent bone. Probably the graft may remain alive when the circulation is established early, otherwise the process is one of gradual substitution. The end-results

are the same in both though longer protection is required when the roentgenograms demonstrate absorption.

This discussion is based upon facts observed in 50 cases in which operative measures were employed by the technic previously described. There were five females and 44 males; the youngest 16 and the oldest 56, the average being 32. Other facts as to age and location are demonstrated in Table I.

TABLE I

Age		Location	
Below 20	6	Upper third	5
20–30	17	Middle and upper third	5
30–40	14	Middle third	14
40–50	8	Middle and lower third	13
50–60	4	Lower third	12

Of the 50 cases, there were 12 in which radical measures were employed at a time when union may possibly have been secured by conservative measures. Eight of these were at the end of three months and four were under three months. Of the remaining 38, in which undoubtedly a permanent status of nonunion had been reached, from four months to eight years had elapsed since the fracture, the average time being 14.7 months. The roentgenogram revealed the usual well known anatomic types of fractures of the humerus: transverse, short oblique, often with loose fragments, and long oblique or spiral. The latter was found in only one instance and will be discussed later. Nonunion of the humerus in transverse fractures is said to be more frequent but in such a large percentage of our cases there had been previous operations that the original anatomic features could not be determined.

A survey of the roentgenograms of the 38 cases in which an unquestionable status of nonunion had been reached demonstrates three different types: (1) Those in which there is a definite pseudo-arthrosis with a shallow cup, usually on the proximal fragment, which is due to the greater vitality as functional use is greater and comminuted fragments fuse to this fragment. In this type, condensation of the bone with obliteration of the marrow cavity by new formed bone is often found. This is an inferior quality of bone comparable to dense scar tissue. (2) Osteoporosis with rapid irregular absorption of lime salts, as evidenced by mottling of the fragments, extends for considerable distance on the shaft from the site of the fracture, as demonstrated by the roentgenogram. This condition is evidently due to a vasomotor phenomenon of the sympathetic nervous system as a reflex instigated by acute trauma. After every fracture there is more or less absorption of the ends of the fragments with increased circulation, probably from the same cause. This phenomenon is also frequently observed after comparatively slight trauma, such as the spraining of an ankle, after operation on joints and in acute infectious processes. In other words, it may be regarded as a natural process of healing which becomes exaggerated to a pathologic degree.

(3) Bone atrophy of disuse is apparent by the paleness of the osseous structure, with diminution of the transverse diameter. The fragments also lose their natural contour and become conical. The marrow is increased at the expense of the cortex, which becomes very thin. At operation excessive fatty infiltration of the marrow is found. Bone atrophy of disuse is exaggerated after the elapse of many months or years, and is due to the loss of physical stimulus of function which maintains the normal size of the bone by cellular activity. It must be distinguished from osteoporosis. In other words, there are two distinct types of osseous atrophy, and possibly two separate physiologic processes.

In the 49 cases in which the massive onlay graft was applied there were three failures, or 93.8 per cent in which solid bony union was procured. The fiftieth case was a long oblique fracture in which fixation was secured without the massive graft, by transfixion of the fragments with autogenous bone nails, resulting in solid union. Of the three in which union could not be induced, two were gunshot fractures with loss in the continuity of the bone. In one of these union was successfully secured after a second operation, so that the final result was excellent. The other gunshot injury was in a stout Negro woman with a four plus Wassermann, and preliminary antisyphilitic treatment was administered. The graft in this case did not secure sufficient fixation due to error in technic. In the third case the graft was most efficiently applied to the bone, but the fragments were not closely approximated, with a space of possibly one-half inch between the fragments. In four cases in which there had been previous injury to the soft parts on the lateral aspect of the arm, the graft was applied to the posterior surface but did not remain sufficiently approximated due to the tendency of posterior bowing, which induced slight separation of the graft from the fragments. The graft should in all cases be applied to the lateral surfaces of the humerus where there is no tendency to displacement.

In the group of 12 cases in which the operation was carried out within four months after the initial fracture, there were no failures. In the 38 cases in which more than four months had elapsed there were three failures, making the percentage of successful results in this group 92.1 per cent, or the entire group of 50 cases, 94 per cent. This is approximately the same percentage as in the previous report of the first 104 cases of ununited fractures of the long bones treated by the onlay graft. The complications are also analogous. There were four postoperative infections, two of which were gunshot fractures, but a firm union was secured in all, despite virulent infection. In the first report there were 17 infections with but one failure to unite. In spite of virulent infection the graft is well tolerated, and in those which sequestrate, fixation is maintained sufficiently long to secure union. Of the 50 cases 12 were compound fractures of which six were gunshot injuries. In eight cases there was a radial nerve paralysis following the primary injury, four of which recovered, two without surgery. There was a definite tourniquet paralysis in four cases, all of which recovered before

normal function of the arm could be permitted. This complication can be avoided by the employment of a pneumatic tourniquet, with which the exact pressure on the arm can be estimated. No amount of care can prevent the injury of nerves by the type of tourniquets in common use, regardless of the precaution used.

The advantages of this procedure are maximum fixation and osteogenesis, which can be routinely secured, and no foreign material is employed. From personal experience, I believe that the employment of endosteum and cavernous bone more efficiently promotes osteogenesis than any other type of graft. By the onlay method no bone is removed from the fragments, but a considerable amount of new bone is added and the normal dimensions and strength are finally increased. Should failure or sequestration, with or without infection, occur, the bone is in a much better condition for future treatment than if a large portion of both fragments is excised in the process of operation.

Due consideration must be given to the physiologic principles of bone regeneration at the time of operation and in the cultivation of osteogenesis by efficient after treatment, until repair and functional restoration of the entire member is complete.

REFERENCE

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MEMOIRS

JOSEPH COLT BLOODGOOD

1867–1935

JOSEPH COLT BLOODGOOD was born in Milwaukee, November 1, 1867. He was descended from a family long prominent in legal circles. He was graduated from the University of Wisconsin with the degree of B.S. in 1888, and from the University of Pennsylvania with the degree of M.D. in 1891.

JOSEPH COLT BLOODGOOD, M.D.

A year later he joined the Staff of the Johns Hopkins Hospital as Assistant Resident Surgeon. From that time on his promotion was steady through all grades, until at his death he was Adjunct Clinical Professor of Surgery in the Johns Hopkins University and Hospital, and Director of the Garvan Research Laboratory. He was also Chief Surgeon to St. Agnes' Hospital, and Director of the Cancer Research Fund bearing his name.

While Doctor Bloodgood always retained an active interest in general surgery, he early devoted himself to the study of surgical pathology. In later years, cancer research, more especially its cause, early recognition and prevention, attracted his attention. To this end he was an ardent advocate of publicity in all forms, in order to educate the public to seek medical advice early. As a means of stimulating the profession in the prompt recognition of the disease, he was the chief sponsor for a series of meetings of a group of those especially interested in the study of malignant diseases.

Doctor Bloodgood's contributions to scientific medicine have been more especially along the lines just indicated. But early in the history of the Johns Hopkins hospital, Doctor Bloodgood, as his surgical resident, was of material assistance to Professor Halsted in working out various problems in surgical technic, more especially the development of the use of rubber gloves.

Doctor Bloodgood's scientific enthusiasm was unbounded; his energy tireless. While his methods of thought and action did not always conform entirely to orthodox customs, and hence were at times misunderstood by some, yet to the inner circle of his close friends and chosen associates he was ever an interesting personality, an inspiring teacher, a great surgeon, and a loyal friend.

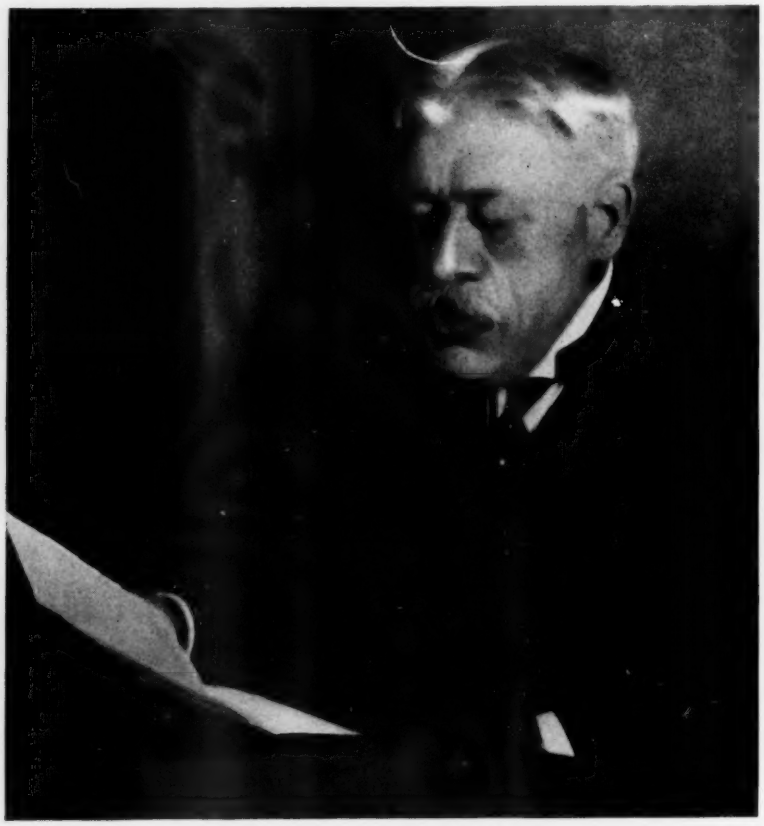
JOHN M. T. FINNEY.

WILLIAM BRADLEY COLEY

1862–1936

"Ffight on, my men," sayes Sir Andrew Barton,
"I am hurt, but I am not slaine;
I'le lay mee downe and bleed a-while,
And then I'll rise and fight againe!"

How often have we who have known Dr. William B. Coley heard him recite the challenging lines of that old Scottish ballad! In looking back over



WILLIAM BRADLEY COLEY, M.D.

his life of three-score and 14 years, one is impressed by the fact that it was indeed a series of hard fought battles—battles for what he believed to be the right, not only in the world of science but in affairs of everyday life. His passing on April 16, 1936, has left us with a sense of loss of great leadership.

For one who has been in close association with Doctor Coley for a period

of so many years as I have, it is difficult if not almost impossible to assume the dispassionate rôle of biographer. However, his achievements in the field of surgery as well as in that of cancer research stand out with such Appalachian clearness that one can point to these lofty peaks with little difficulty.

Doctor Coley believed that heredity played the most important part in a man's life; and it would seem to have had a strong influence on his own. He was born in Westport, Connecticut, on January 12, 1862, of an old New England family. His paternal ancestor was Samuel Coley, one of the forty-nine free planters who settled in Milford in 1639. His maternal ancestor was John Wakeman of Benchley, England, a "freeman of the courte of New Haven" (1639) whose son, the Reverend Samuel Wakeman (Harvard, 1655), was one of the first Congregational ministers of Fairfield, Connecticut.

Doctor Coley entered Yale College in the fall of 1880 and was graduated with the degree of Bachelor of Arts in 1884. He taught Latin and Greek at the Bishop Scott Government School in Portland, Oregon, for two years, and then entered the Harvard Medical School in 1886 where he completed the three-year course in two years and was graduated in 1888. As he often remarked, he had taken up the study of medicine and surgery at a most opportune time—when the older surgery with the high mortality from infection was just beginning to be replaced by the newer surgery based on Lister's recognition of the principle of antisepsis. After a strenuous competitive examination, Doctor Coley was appointed an intern on the surgical service of the New York Hospital under Dr. Robert F. Weir and Dr. William T. Bull.

Even at that early date (1888) he showed a keen interest in the subject of sarcoma; and in going over the files of the New York Hospital he came across a case that made a very deep impression upon him. This was a four-times recurrent, apparently inoperable sarcoma of the neck which had apparently entirely disappeared following an attack of facial erysipelas. Doctor Coley was very anxious to learn the end-result—no mention of it was made in the hospital history—so he patiently traced the man from one tenement house to another until he finally located him and learned that he was still in excellent health seven years after the attack of erysipelas. This observation led him in 1891 to start a series of experiments in which he attempted to produce erysipelas in patients suffering from inoperable cancer. Doctor Bull was greatly interested in the work and made it possible for him to treat 12 patients at the New York Cancer Hospital (now the Memorial Hospital) in a special pavilion erected by Mr. Archer M. Huntington. After considerable experimentation, a preparation consisting of the killed cultures of erysipelas combined with the Bacillus prodigiosus, was produced which was found to have a marked inhibitory influence upon certain types of malignant tumors, especially sarcoma. This is the preparation known as Coley's toxins, which is in use today. From the very beginning, however, Doctor Coley advocated the toxins only for inoperable sarcoma or as a prophylactic measure

after operation for bone sarcoma, and not for malignant tumors in general. In 1909, in an address before the Royal Society of Medicine, he gave a detailed description of his method of treatment and the results obtained with it; and in the discussion which followed, Sir Henry Butlin in commenting on the different kinds of so called "cancer cures" stated: "With the exception of Doctor Coley's method, scarce a single one has survived." Doctor Coley's faith in the toxins never wavered, and the large number of five year recoveries of inoperable malignant tumors that he was able to report in his address before the Royal College of Surgeons of England in October, 1935, was convincing proof that his faith had been well founded. At that meeting he was elected to honorary fellowship in the Royal College of Surgeons.

Most of Doctor Coley's work with inoperable malignant tumors was carried on at the Memorial Hospital, with which institution he was connected for more than 40 years, and on the Executive Committee of which he was still serving at the time of his death. His interest in this field was so keen and contagious that in 1902, one of his patients, Mrs. C. P. Huntington, influenced more or less by his enthusiasm, donated the sum of $100,000 for the establishment of the Collis P. Huntington Fund for Cancer Research of the Memorial Hospital—the first cancer research fund ever started in America.

It is rarely that an individual excels in more than one field; but very early in his career Doctor Coley achieved great success in operating for the radical cure of hernia. After reading his report (1897) of a series of 360 antiseptic operations for the radical cure of hernia, in which only one death had occurred and that from ether anesthesia given to a child with weak lungs, Lord Lister, at an important function in London, made the following comment: "An achievement like that is enough to cause gladness in the heart of any man who loves his fellow man. I cannot help remarking that such results could not have been obtained by the mere recognition of the truth of the importance of antiseptic principles. Such success implied that the operator was not only convinced of the truth of those principles, but also that he vigilantly maintained throughout his operations that earnest care which is necessary to prevent those principles being contravened."

Doctor Coley was one of the first in America to adopt the Bassini method of operating for the radical cure of hernia (1890) and in his recent contribution to the Bassini Bicentennial Volume compiled by the surgeons of the University of Padua, Italy, he reiterates his faith in the operation and maintains that it still remains the method of choice in most countries.

After serving as associate and then attending surgeon of the Hospital for Ruptured and Crippled, in 1924 Doctor Coley was appointed Surgeon-in-Chief, which position he held until 1931, when he became Emeritus. In 1908, he was appointed the first surgeon of the New York Central Railroad, serving as Chief Surgeon until January, 1932, when he had reached the retirement age. Another of his professional connections which was a source of great pleasure and satisfaction to him was the Mary McClellan Hospital

in Cambridge, New York, built by one of his classmates, Mr. Edwin McClellan in 1918. Doctor Coley helped to plan the hospital, to obtain an excellent resident staff, and in every way to maintain the highest possible standards for a small hospital in a rural community. As Surgeon-in-Chief, he made weekly and later monthly visits, doing much of the major surgery. He enjoyed coming in contact with the family doctor of these rural communities and was unstinting in his praise of the latter's sterling qualities.

A glance at his bibliography shows him to have been a prolific writer. His contributions deal not only with hernia and cancer, but include many essays in other surgical fields.

English literature was his greatest hobby; to him the great masterpieces of the world, apart from their solace and charm, were the master instruments of a solid education.

In 1897, at the age of 36, Doctor Coley was elected a fellow of the American Surgical Association—the youngest surgeon ever to have been elected. In 1902, he became a fellow of the Southern Surgical and Gynecological Association. He was a charter member of the American College of Surgeons; in addition he held membership in the New York Surgical, the New York Pathological, the Radiological, and the Harvard Medical societies, as well as in the American Association for Cancer Research, the American Society for the Control of Cancer, and the Association of Surgeons of Great Britain and Ireland (Honorary).

The same rich fulness, which crowned his professional life was apparent in his personal life as well. In 1891, he was married to Miss Alice Lancaster, of Newton, Mass. She and their two children, Dr. Bradley L. Coley and Mrs. William Boone Nauts, survive him. One son, Malcolm, died in his sixth year.

We who were associated with Doctor Coley, and who recognized the sterling qualities of his rare personality, realized that there was one quality which surpassed all others, even his boundless optimism, and that was his ever-readiness—in fact, eagerness—to lend a helping hand. None appealed to him in vain. He loved his fellowmen.

In closing, I would repeat the lines uttered at the time he received his degree of Honorary Master of Arts from Harvard University in 1911 (one year after his Alma Mater had conferred the same degree):

"William Bradley Coley, surgeon, medical discoverer, and director of medical research; who learned to cure by surgery ills that had foiled its art, and without surgery others beyond its reach."

CARL G. BURDICK

CARL ARTHUR HEDBLOM

1879–1934

CARL A. HEDBLOM was born in Boone, Iowa, on March 5, 1879. He died suddenly on June 6, 1934, at Toronto, Canada, while attending a meeting of the American Surgical Association. His death was caused by coronary thrombosis and occurred after an illness of 48 hours. The news of his sudden

CARL ARTHUR HEDBLOM, M.D.

death came as a great shock to his many colleagues and friends throughout this country and Europe.

Doctor Hedblom was educated at Colorado College, from which he received a degree of B.A. in 1907. In the following year he received a degree of M.A. and in 1921 an honorary D.Sc. from the same college. He was graduated from the Harvard Medical School in 1911 and served his internship and surgical residency under Dr. Maurice Richardson at the Mas-

sachusetts General Hospital from 1911 to 1913. In 1913 he went to Shanghai, where he was professor of surgery at the Harvard Medical School in China until 1916.

He entered The Mayo Foundation as a fellow in surgery on October 1, 1916. He was head of the section on general and thoracic surgery at The Mayo Clinic from January 1, 1919, to September 15, 1924. He received his degree of Ph.D. in surgery from the University of Minnesota in 1920. He was associate professor of surgery of The Mayo Foundation, Graduate School, University of Minnesota, in charge of the division of thoracic surgery during 1923 and 1924. He was professor of surgery at the University of Wisconsin from September, 1924, to February, 1926, when he accepted the position of professor of surgery at the University of Illinois, which position he occupied at the time of his death.

He was under appointment as Major, Medical Corps, United States Army, and was ordered to report for duty at the time of the armistice which concluded the World War.

Doctor Hedblom was a member of the Society of Clinical Surgery, of the American Surgical Association, of the Western Surgical Association, and of the American Medical Association. He was a member and past president of the American Association for Thoracic Surgery, a fellow of the American College of Surgeons and a member of the Alumni Association of The Mayo Foundation, of Sigma Xi, and of Phi Beta Kappa.

Few surgeons have had a broader training or more extensive experience in surgery than had Doctor Hedblom. In the last 15 years of his life his interest was confined chiefly to thoracic surgery. He entered this field during its early development in this country and obtained an international reputation for his work. It was fortunate for this branch of surgery that a man of his judgment, courage and conservatism became interested in it at an early date, for he was a tireless worker as well as an extensive writer and did much to stabilize the fundamental principles underlying surgery of the thorax. One of his most important contributions to the principles of thoracic surgery was to emphasize the importance, when possible, of dividing extensive operative procedures into stages. Those who were fortunate enough to know Doctor Hedblom will always remember his strong character, his frank friendliness, his cheerful smile and hearty laugh. These characteristics, combined with his inherent honesty and sincerity of purpose, earned for him the greatest admiration and respect of his colleagues and the confidence of his patients. His memory will always be a source of inspiration to progress and achievement.

In 1913, shortly before Doctor Hedblom completed his service in the Massachusetts General Hospital, he married Eleanor Pease, who with three sons and a daughter survive him.

STUART W. HARRINGTON, M.D.

JONATHAN MAYHEW WAINWRIGHT

1874–1934

By the death of Jonathan Mayhew Wainwright on August 3, 1934, the American Surgical Association lost one of its most valued members. He was Vice President of the Association in 1930.

Jonathan Mayhew Wainwright, M.D.

Doctor Wainwright was born February 20, 1874, in Hartford, Connecticut; the son of William Augustus Muhlenberg Wainwright, M.D., whose father was Bishop Jonathan Mayhew Wainwright. His mother was Helena Barker Talcott. He came from old New England stock and was descended from nine colonial governors. He was educated at Hartford High School, and received his B.A. degree at Trinity College, Hartford;

and his M.D. degree at the College of Physicians and Surgeons, New York, in 1899. Trinity College later conferred upon him an honorary M.A. degree. He served as intern at St. Luke's Hospital in New York from 1899 to 1901 and was married immediately upon leaving the hospital to Jessie Bell Hart of Englewood, N. J. While an intern in the hospital he showed deep interest in his medical work and serious study of the problems thereof. In the few hours for recreation which an intern might find in the evening, he occupied himself in the laboratory, cutting and studying pathologic slides which even then formed the nucleus and ground work for the study which he carried on through the rest of his medical career.

Immediately upon finishing his internship, although a young man, he became Surgeon-in-Chief at the Moses Taylor Hospital in Scranton, Pa., which position he occupied up to the time of his death. He served during the Spanish-American War as Adjutant in the First Connecticut Regiment. In the World War, he served overseas successively as Major, Lieutenant Colonel and Colonel in the Medical Corps, and received a citation from General Pershing.

Doctor Wainwright was not only an earnest student but a prolific contributor to general surgical literature, as well as many public health problems. He was always interested in cancer research, particularly in cancer of the breast, and carried on a correspondence and made a study of not only his own cases, but also of material supplied to him by his surgical colleagues in other cities. His slides of complete cross sections of carcinomatous breasts were beautifully prepared and most carefully studied by him. He was President of the American Society for Control of Cancer in 1930, also Chairman of the Pennsylvania State Cancer Commission, the first in the field of state work. He was director of the Cancer Research Clinic, of Scranton, Pa.

In 1930, he made a four-months' trip through Uganda, Kenya and Tanganyika for the purpose of cancer research among the native African tribes. In addition, as evidence of his broad interest in other problems of public health, he organized, in 1902, the West Mountain Sanatorium, in Scranton, for the treatment of tuberculosis, and in 1907 he made a study of, and reported on, the Scranton typhoid epidemic which had occurred in the previous year.

While Doctor Wainwright's chief interest was always some phase of the cancer problem, and although during his later years most of his surgical contributions pertained to this subject, particularly breast cancer, a list of his surgical contributions covers almost every phase of general surgery.

His scientific mind, the concentration of purpose with which he would pursue a problem, his devotion and interest in his professional work, made him an outstanding surgeon, and one of the most valuable men to both the profession and public of his adopted state of Pennsylvania. His many friends both in the American Surgical Association and in the profession at

large, as well as of the public generally, have lost one who will be hard to replace.

It is indeed an ironical and sad commentary on the progress of the knowledge of the disease to which he had devoted so much of his life's study, that this same disease should have progressed to such a degree in his own case, that the condition was inoperable before a diagnosis could be made.

JOHN DOUGLAS

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